SCHOOL SCIENCE AND MATHEMATICS

VOL. X NO. 5 CHICAGO, MAY, 1910 WHOLE NO. 79

RELATION OF PURE AND APPLIED SCIENCE RESPECTIVELY TO SECONDARY EDUCATION.[1]

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The field which this subject covers is so great that, for the limited time at my disposal, it seems best to confine my inquiry to some one phase of the question. I have chosen, therefore, a topic that has interested me for some time, one which is finding expression among science teachers in the agitation for a general science course for the first year of the high school course of study. I shall inquire into the position of science in the curricula of the high schools, especially as to whether science is receiving the attention it deserves in comparison with its importance in everyday life and in comparison with other departments in the high school. The question also as to whether the applied sciences now being added to the curriculum of many schools are being articulated with the pure science courses already in the course of study is an important one.

It does not seem very necessary to call attention to the increasing importance of science in everyday life. Everyone is familiar with the facts of the achievements of science, especially those that are spectacular, but these achievements are becoming such an everyday matter taken for granted, that one must pause to think, before he realizes fully how far-reaching the field of science really is, and how fast it is increasing these days, with the advances in electricity, transportation, gas, sanitary and medical science, agriculture, forestry, etc. Take the one field of sanitary science, the advance from simple guesswork to accurate scientific knowledge has meant the saving of untold thousands of lives, and its work for good has just begun. Its field is in every home, more important in the homes of the ignorant and poor than in the homes of the educated and rich.

[1] Read before the Illinois Academy of Science at Urbana February 19, 1910.

Few can doubt that agriculture will, in the near future, be rescued from the ruts into which it has fallen and put upon a scientific basis. Many are beginning to recognize that the hope of a prosperous future of our country depends upon this.

In view of the supreme importance of science in human life, one would expect to find it occupying a commanding position in the curriculum of every secondary school. But educators are conservative. Tradition and custom are binding forces that tend to hinder rational response to changed conditions. A glance at the history of educational methods shows this tendency toward conservatism to be very strong.

In medieval times education was solely for those who did not work with their hands. The classics furnished the basis for educational training, for indeed there was little else, and it answered the purpose. In time, human freedom gradually broadened and with it education reached down from the idler and scholar to the workers. As education became more widespread and free schools were established the number fitting for college greatly increased. Finally, little more than half a century ago, the first public high schools were established. But instead of these schools growing up out of the elementary schools, they were patterned after the colleges.

The colleges had been the bulwark of conservatism, and till a few years ago comparatively the classics still held their place in the front rank of what was deemed best for educational training, almost a fetich to the educators of the colleges. The men who were called to make the curricula of the high schools came from the colleges, and we need not be surprised when we find the languages still occupying the front rank in the high schools, even more than in the colleges themselves.

Let us now inquire into the actual conditions we may find in the curricula of the high schools. I will first analyze the course of study of the Chicago high schools, since I am more familiar with those schools. Some explanation of terms is necessary for a clear understanding of the figures. High schools usually give one credit toward graduation for five recitations per week in one subject for a year, two laboratory periods counting as one recitation period. Manual training, music, drawing, and domestic science usually require two periods of work as an equivalent to a recitation period. The unit course then is five recitations per week in one subject for one year. But as a few schools, including those of Chicago, have many courses with only four or even fewer

recitations per week, giving, however, corresponding credit. It will be more convenient in this paper to use hours (periods) in place of unit courses, understanding that five hours constitute a unit course.

Chicago offers a total of 211 hours' work, about forty-two courses, in her high schools, not including manual training which is localized in a few schools and omitting domestic science and art, which are not fully organized. By departments the courses are distributed as follows:

Foreign language	91	hours,	or about	45% of the total number of hours offered.
English	16	"	"	8%
History	20	"	"	10%
Mathematics	14	"	"	7%
Commerce (including arithmetic)	26	"	"	13%
Science	24	"	"	12%
Music, drawing, etc.	20	"	"	10%

The humanities, language and history, constitute 63% of the total courses offered against 37% in all other subjects. It will be noticed, also, that the commercial department, one of the most recently established, offers a greater number of hours than science, twenty-six hours of commercial work to twenty-four hours of science and this is counting physiology, geology and astronomy as sciences, though they are not given with laboratory courses in the Chicago schools, and should really not be counted as science. Excluding these subjects, Chicago offers only nineteen hours' work in the laboratory sciences. Excluding from the foreign language group Greek and Spanish, which are not given in most of the schools, Chicago offers 57 hours in foreign languages to 19 hours in science, exactly three to one.

In order to compare this with other schools of the state I sent out fifty requests for courses of study, twenty-five to township high schools and twenty-five to city and village high schools, and received forty replies. With these forty courses of study I constructed a table showing the number of hours offered in each department and showing also the distribution of the science courses offered by each school.

Studying the table I find that the ratios remain about the same as in Chicago except that there are fewer courses in the foreign languages and often more in the sciences (not including domestic science). The courses offered in the foreign languages in the various schools range from 20 hours to 95 hours in amount.

COMPARATIVE TABLE OF HIGH SCHOOLS SHOWING:

(1) The total number of "hours" (periods*) work offered in all departments and in each department;

(2) The courses in science by years.

TOWNSHIP HIGH SCHOOLS.	Total number of periods ("hrs.") offered in all dep'ments.	Total periods* ("hrs.") offered in each dept.									Courses in Science by Years (Including applied sciences).											
		Foreign language.	English.	History.	Mathematics.	Commercial.	Science (pure).	Domestic Science	Man. Training.	Agriculture.	FIRST YEAR.	Semesters	Periods per W'k	SECOND YEAR.	Semesters	Periods per W'k	THIRD YEAR.	Semesters	Periods per W'k	FOURTH YEAR.	Semesters	Periods per W'k
	* **	*																				
Savanna	117	30	16	15	12½	21½	20			2	Physiology Phys. Geog.	1 1	7 6	Zoölogy Botany	1 1	7 7	Chemistry	2	7	Physics	2	7
Pontiac	127½	30	20	20	17½	20	20				Phys. Geog. Physiology	1 1	5 5	Zoölogy Botany	1 1	7 7	Physics	2	5	Chemistry	2	5
Streator	180	45	20	20	20	30	20	15	10		Phys. Geog. Dom. Science	1 2	5 5	Botany Zoölogy Dom. Science	1 1 2	7 7 5	Physics Physiology Dom. Science	2 2 2	7 1 5	Chemistry	2	7
New Trier	237	75	20	20	20	40	25	12	20		Phys. Geog. Dom. Science	2 2	7 5	Botany Zoölogy Dom. Science	2 2 2	7 7 5	Chemistry Dom. Science	2 2	7 5	Physics Dom. Science	2 2	7 5
Sterling	135	45	20	15	17½	5	32½				Biology Phys. Geog. Physiology	2 1 1	10 5 5	Botany Zoölogy	2 2	10 10	Physics	2	7	Chemistry Astronomy	2 1	8 5
Geneseo	124	30	20	25	15	15	21	4	4		Phys. Geog.	2		Zoölogy Physiology Dom. Science	1 1		Botany Physics Dom. Science	2 2		Chemistry	2	
Evanston	155	65	15	20	20		25		10		Phys. Geog. Physiology	1 ½	5 5	Botany Zoölogy	2 2	7½ 7½				Physics or Chemistry	2	7
Waukegan	195	50	20	15	15	35	25	10	10		Phys. Geog. Dom. Science	2 2	7 10	Zoölogy Botany Dom. Science	2 2 2	8 8 10	Physics	2	7	Chemistry	2	7

La Salle	260	45	20	15	17½	30	32½	20	20	20	Gen. Science Phys. Geog. Physiology Dom. Science	1 10 1 10 1 5		Biology Botany Zo.logy Dom. Economy	2 10 2 10 2 10		Physics Dom. Science	2 10		Chemistry Agriculture (four year course)	2 10	
Centralia	162½	30	20	20	15	35	22½	20			Phys. Geog. and Gen. Science Dom. Science	2 2		Dom. Science Zoölogy Botany Physiology	2 1 1 1		Physics Dom. Science	2 2		Chemistry Dom. Science	2 2	
La Grange	150	45	20	15	17½	10	22½		20		Botany	2	5	Zoölogy	2	5	Chemistry Phys. Geog.	2 5 1 5		Physics	2	5
Murphysboro	124	40	20	20	15		20	6	8		Physiology Phys. Geog. Dom. Science	1 7 1 7 2 3		Zoölogy Botany Dom. Science	1 7 1 7 2 3		Chemistry	2 7		Physics	2	7
Joliet	245	95	30	30	25	20	42½			2½	Physiography	2		Botany	2		Physics Adv. Botany Zoöl. and Physiol. Agronomy	2 1 2 1		Adv. Physics Chemistry Chem. Inorganic Geol. and Astron.	2 2 2 2	
Marshall	115	35	20	15	15	10	20				Physiology Phys. Geog.	1 5 1 5		Biology	2 7		Chemistry	2 7		Physics	2	7
Gilson	100	25	20	15	15	10	15				Physiology	2 5					Zoölogy Botany	1 1		Physics	2	
De Kalb	150	35	20	15	17½	20	20	5		5	Agriculture Zoölogy Physiology Dom. Science	1 1 1 2 3		Agriculture Botany Phys. Geog. Dom. Science	1 1 1 2 3		Physics	2		Chemistry	2	
Oak Park	182½	65	20	20	20	15	25		17½		Gen. Science	1 7		Phys. Geog.	1 7		Botany Zoölogy Physics	2 7 2 7 2 7		Chemistry	2	7
Princeton	160	40	20	15	15	30	30	5		5	Phys. Geog. Physiology	1 5 1 5		Zoöl. and Bot. Botany Agriculture	2 7 2 7 2 7		Physics Dom. Science	2 7 2 8		Chemistry	2	7
Ottawa	187½	70	20	10	15	25	27½	10	10		Gen. Science	2 3		Botany Zoölogy	2 2		Physiography Chemistry Dom. Science	2 5 2 7 2		Physics Dom. Science	2 2	7
Lockport	200	30	20	12½	27½	30	35	20	20	5	Botany Phys. Geog. Physiology Dom. Science	2 7 1 6 1 5 2 4		Geology Zoölogy Dom. Science	1 5 1 7 2 4		Agriculture Chemistry Dom. Science	2 7 2 7 2 4		Physics Surveying Astronomy Dom. Science	2 1 1 2	7 7 7 4
Clyde							20				Phys. Geog.	2 5		Zoölogy	2 6		Physics	2 8		Chemistry	2	8

*Periods or "hours" as used in this table except under "Courses in Science by Years" mean recitation periods, laboratory double periods being reduced to equivalent recitation periods so that all departments may be compared on an equal basis.

**The amounts given in this column do not include music, drawing, and other special studies.

Note.—While the utmost care has been used to secure accuracy in this table, it was not easy in some cases to interpret the statements of the courses of study from which the figures were obtained, and thus slight errors may have been made in the number of periods credited.

CITY AND VILLAGE HIGH SCHOOLS.	Total No. of periods* offered in all departments.	Total periods ("hrs.") offered in each dept.									Courses in Science by Years (Including applied sciences).												
		Foreign language.	English.	History.	Mathematics.	Commercial.	Science (pure).	Domestic Science.	Man. Training.	Agriculture.	FIRST YEAR.	Semesters	Periods per W'k	SECOND YEAR.	Semesters	Periods per W'k	THIRD YEAR.	Semesters	Periods per W'k	FOURTH YEAR.	Semesters	Periods per W'k
Alton	* ** 125	* 40	20	15	15	10	25				Phys. Geog.	1	4	Botany	1	4	Physics	2	7	Chemistry	2	7
											Physiology	1	4	Zoölogy	1	4				Geology	1	4
																				Astronomy	1	4
Aurora	160	35	20	20	20	20	20	10	10		Phys. Geog.	2	7	Botany	1	7	Chemistry	2	7	Physics	2	7
											Dom. Science			Zoölogy	1	7						
														Dom. Science								
Canton	132½	30	20	20	15	20	27½				Phys. Geog.	2		Botany	1		Physics	2		Chemistry	2	
											Physiology	1		Zoölogy	1		Geology	1				
																	Astronomy	1				
Champaign	150	35	20	15	15	35	20		10		Phys. Geog.	1	5	Biology	1	7	Physics	2	7	Chemistry	2	7
											Biology	1	7	Physiology	1	7						
														Physiology	1	5						
Charleston	112½	20	20	12½	15	7½	20	7½	10		Physiography	1		Zoölogy	1		Chemistry	2		Physics	2	
											Botany	1		Physiology	1					Dom. Science	2	2
											Dom. Science	2	2	Dom. Science	2	2						
Clinton	133	30	20	15	17½	20	22½	8			Physiology	2	5	Physiography	1	5						
											Botany	1	7	Zoölogy	1	7	Chemistry	2	7	Physics	2	7
											Dom. Science	2	4	Dom. Science	2	4	Dom. Science	2	4	Dom. Science	2	4
Belleville							22½				Physiology	2	5							Physics	2	7
											Physiography	1	5	Botany	2	5	Chemistry	2	7			
Elgin	172½	35	20	15	17½	20	27½	5	10		Physiology	1	5									
											Phys. Geog.	2	5	Botany	2	7						
											Dom Science	2	7	Zoölogy	2	7	Chemistry	2	8	Physics	2	8

											Zoölogy	1												
											Botany	1		Physics	2		Chemistry	2					
Galesburg	123	25	20	15	15	25	15	3	5		Physiology	1		Dom. Science	2		Dom. Science	2					
Mattoon	107½	30	20	17½	15	5	20				Physiology	1	5	Zoölogy	1	7							
											Phys. Geog.	1	5	Botany	1	7	Chemistry	2	7	Physics	2	7
Danville	170	45	20	25	15	35	25	5			Phys. Geog.	2	5				Physics	2	8	Chemistry	2	8
											Dom. Science	2	5	Botany	2	5	Zoölogy	2	5			
											Botany	2	7	Zoölogy	2	7	Chemistry	2	7	Physics	2	7
Moline	175	40	20	15	17½	20	25	6	25		Dom. Science	2	4	Phys. Geog.	1	5							
											Physiology	1	3	Dom. Science	2	4							
											Bot. or Zoöl.	2		Zoölogy or Bot	2								
											Dom. Science	2		Dom. Science	2		Physics	2		Chemistry	2	
Freeport	177½	35	20	10	17½	35	20	20	20		Agriculture	2		Agriculture	2		Dom. Science	2		Dom. Science	2	
Decatur	137½	45	20	20	20	10	22½				Phys. Geog.	1	5	Zoölogy	1	7	Chemistry	2	7	Physics	2	7
											Physiol.	1	5	Botany	1	7				Astronomy	1	5
Pekin	140	40	20	15	15	30	17½				Phys. Geog.	1		Biology	2		Physics	2		Chemistry	2	
																	Zoölogy	2	7			
											Phys. Geog. and			Botany	2	7	Physics	2	7	Chemistry	2	7
Rockford	175	45	20	15	17½	30	27½		15		Physiology	2	5	El. Chem. & D. Sc.	2	3	Dom. Science	2	3	Astronomy	1	5
											Physiography	1	5	Zoölogy	1	7						
Springfield	305	60	20	22	20	25	20	20	20		Physiology	1	7	Botany	1	7	Physics	2	7	Chemistry	2	7
											Phys. Geog.	1		Zoölogy	1							
Watseka	120	20	20	15	15	30	20				Botany	1		Physiology	1		Physics	2		Chemistry	2	
														Zoölogy	1	7						
Peoria	185	65	20	15	20	35	20		10		Phys. Geog.	2		Botany	1	7	Physics	2	7	Chemistry	2	7
											Physiology	1		Biology	2		Chemistry	2		Physics	2	
Kewanee	137½	35	20	15	17½	30	20	7½			Phys. Geog.	1		Dom. Science			Dom. Science			Dom. Science		
											Phys. Geog.	1	5	Zoölogy	1	7						
Paris	100	30	20	10	15	5	20				Physiology	1	5	Botany	1	7	Chemistry	2	7	Physics	2	7
														Bot. and Zoöl.	2	6	Physics	2	6	Chemistry	2	6
											Phys. Geog.	1½	6	Botany	2	6				Geology	1	4
Chicago	191	91	16	20	14	26	24	†	†		Physiology	½	4	Zoölogy	2	6				Astronomy	1	4
	†Special Schools																							

While the courses offered in science range from 15 hours to 35 hours, averaging 41 hours of foreign language to 23 hours of science. No distinction is here made between laboratory science and text-book science since many of the courses of study did not indicate the methods used in the school. Physiology is required and is usually given without an accompanying laboratory course. I estimate that 20 hours is about the correct average of the laboratory sciences, or about 13% of the average total number of hours offered.

Of equal importance with the amount of time given, and growing directly out of this, is the organization of the courses. In Latin, for example, we find a well-organized four year course, each succeeding year building on the work of the preceding year, the whole forming a graded series with one object in view. The same is true of the other foreign languages and of English as now taught in the schools. In history the courses are consecutive, beginning with ancient history and ending in most schools with American history and civics. In even the latest subjects to be added to the curriculum as in the case of the commercial department, most schools offer a graded series of four to six unit courses preparing for business life.

Now, how is it with science? We find four years' work usually offered, consisting of physical geography and physiology in the first year, botany and zoölogy or a year of either in the second, and physics and chemistry or chemistry and physics in the third and fourth years. This is not, in any sense, a graded course as in Latin, German, and other subjects. It is rather a series of fragments of science, with a half year or whole year devoted to each fragment. The series cannot be called a four year course comparable with the courses in other departments. The principal value of Latin as an educational factor in high schools has been due not so much to any intrinsic merit in the study *per se* as to the carefully graded work on one single subject for four years, thus giving time and opportunity for cumulative development and disciplinary training of the mental activities of the pupil. What would be thought of any school that offered four or more one year courses in as many languages as a substitute for the usual well-graded courses now offered? I wish to quote a passage from a recent address[1] by Professor John Dewey on this point. He says, "Imagine a history of the teaching of the languages which should read like this: 'The later seventies and

[1]Science, January 28th, 1910, page 124.

eighties of the nineteenth century witnessed a remarkable growth of the attention given in high schools to the languages. Hundreds of schools adopted an extensive and elaborate scheme by means of which almost the entire linguistic ground was covered. Each of the three terms of a year was devoted to a language. In the first year Latin and Greek and Sanskrit were covered; in the next, French, German, and Italian; while the last year was given to review and Hebrew and Spanish as optional studies.'" This striking picture by Professor Dewey of the hypothetical history of language teaching very accurately represents the present conditions of science teaching.

How has it happened that the four sciences are arranged as they now are? for the order given above is the usual one. Is it due to grading, forming a graded course in any strict sense of the word? I think not. Anyone acquainted with high school science work knows that this arrangement depends upon other factors and not upon anything inherent in the subjects themselves. Take chemistry and physical geography, one usually given in the fourth year and the other in the first year. Chemistry could be adapted to the first year grade just as well as physical geography so far as anything in the subject itself is concerned. But it happens that chemistry requires a more expensive laboratory and small classes, while physical geography requires a relatively less expensive equipment, is less expensive to run, and larger classes can be handled. Botany and zoölogy do not necessarily depend upon anything taught in physical geography. Physics is given late in the course of study because the college requirements are so stiff that the work cannot be done in the first year. In fact the physics teachers of Chicago find it easy to arrange a course in physics for a proposed first year general science course. I think we can take it as proved that the sciences do not form a graded course comparable with courses in other departments and that the present arrangement is due primarily to extraneous factors such as cost of laboratories, size of classes, and college entrance requirements.

It cannot be said, however, that school officials in planning courses of study consciously intended to slight the sciences. The fault is largely due to the newness of the sciences themselves. There has been action and reaction both in content and in methods of teaching of the sciences, and the end is not reached. The present laboratory method of teaching science in secondary schools does not date back two decades, while the classics have

had the advantage of centuries of teaching in which a great body of principles and methods has been firmly established. But it appears that school authorities have settled down to the belief that this fragmental practice of teaching science is sufficient, for we see a great uniformity in courses of study in this respect. The only straw that indicates a measure of dissatisfaction with the present arrangement lies in the agitation for general science courses in the first year of high school. A few schools have already established such a course.

A good test of the inadequate organization of the science courses is the manner in which the new courses of applied science are being added to the curriculum of many schools. I refer to domestic science and agriculture. One would naturally expect that when these sciences are added to the curriculum of any school they would be articulated with the existing courses in pure science. Before a pupil enters upon a course in an applied science, he ought to have received training in scientific method and habit of thought by studies in pure science, preferably, of course, in those sciences that underlie the applied science in question. Thus chemistry and botany at least should precede or accompany domestic science courses, and all the biological and physical sciences are necessary to adequate teaching of agriculture.

But instead of an attempt to establish well-graded or correlated courses of this sort in which the pure sciences are prerequisite to or coördinate with the course in applied science we find that the new courses are usually being added without any reference to existing courses in pure science. Among the forty courses I have examined only two have any specific requirement of a pure science as a prerequisite. In Chicago, a four year course in domestic science is being planned with no requirements in other sciences. Such an extended course must of necessity repeat in a more or less complete way science work which is already being done in the pure sciences or might be done readily if there were concerted action. This is surely a waste of effort.

But the case with agriculture is much stronger. We may have agriculture of a sort, but not "scientific" agriculture, without the training and facts yielded by the pure sciences. Yet so-called courses in agriculture are being added as if this science were wholly unrelated to other sciences. Often these courses are placed in the early years of the course of study where it is not possible by even an accident for the pupil to have had any

preliminary training in science. The result is, of course, a very superficial and unscientific kind of training.

But after all the school officers who are placing these new courses in the curriculum in response to the demand for them are not to blame for the way it is being done. The arrangement of the pure science courses does not offer any chance for the development of well-graded courses in the applied sciences. Chemistry, which is needed in both agriculture and domestic science, is given in the fourth year in most schools, and physics in the third year. Neither of these studies as now given can be utilized.

Another testimonial to the inadequate and unscientific organization of science in secondary schools is seen in the establishment of separate schools of agriculture and other industrial and technical schools of secondary school grade. These schools are a waste of the resources of the state, for they duplicate the regular schools in all respects save the one department. They are detrimental also in developing a false notion of the relative importance of the various departments of learning. The establishment of these schools is direct condemnation of the existing systems in the regular schools. The reason is not far to seek. The curriculum of the average school is not flexible; on the contrary it is so fixed that needed changes for adjustment to new relations cannot be made without a serious fight with the "ins." Rather than have this fight with an inflexible system, resort has been made to separate schools. Those who have the interests of the public high schools at heart should see to it that there is proper response to the demand for the teaching of agriculture and other industrial subjects in high schools. It should be met by honest endeavor to adjust old relations to new demands, else separate schools are bound to come with consequent division of funds and effort. I may add here an interesting fact in our experience in botany classes in Chicago. Of late boys in our botany classes are strongly attracted by the advantages offered in scientific agriculture, forestry, and sanitary science. This movement is quite marked, though we give only one year of botany with little that suggests agriculture in it. It is a trend countryward from the city of city youth, in contrast with the usual movement.

We may now summarize the points I have made with respect to the position of science in secondary schools. First, the time usually given to science is very small in comparison with the

importance of the subject and in comparison with the cultural subjects, averaging only one half to one third the time given to foreign languages alone. Secondly, the science courses as now planned are fragments of larger subjects and not enough time is spent on any one of them to secure good results either in disciplinary training or in information. Third, the science courses do not form a graded, orderly development of knowledge such as we find in other departments. Each year's work is a detached piece and contributes but little to any other year's work in science. In consequence of the limited time given to each science, there is an attempt to cover too much territory in the alloted time. The pupil, instead of feeling the growth of power and grasp of the subject, is apt to be overwhelmed and paralyzed by matter that he cannot assimilate. Fourth, the pure science courses are organized in such a way that courses in applied science cannot be articulated with them and cannot take advantage of the expensive laboratory equipment of the pure sciences. Fifth, the inflexibility of the curriculum and the inadequate organization of the science courses have resulted in the establishment of many separate schools of agriculture and other industrial sciences.

It is not within the province of this paper to propose remedies for the cure of these defects. If a solution of the problems were easy, it doubtless would have been hit upon long ago. In closing, however, I would like to suggest what I think are the lines the reorganization of science must take. These lines are, first, foundational science in the first year of the high school; second, more time for each of the pure sciences; third, courses in applied sciences should be articulated with the pure sciences; fourth, all high schools in towns and cities tributary to agricultural districts should have a carefully planned course in agriculture and sufficient farming land for practical laboratory work.

It has been indicated that elementary physics and chemistry should be given in the first year as a foundation for courses in applied science and for pure sciences as well. I would suggest a half year of physical geography made less technical than it is usually given, followed by a half year of elementary physics and chemistry or a full year of general science consisting of physical geography and biology for the first half year and the second half year the physical sciences, chemistry and physics. A more advanced type of physiography in this latter case might be elective in the third or fourth year. Physiology now required in the

first year should follow zoölogy in the third year, but if it cannot be taken from the first year, then it might be given without home work in informal lectures on hygiene and physiology as an extra. time being given for it from the home work of all the other studies of the first year. It is now usually given in a perfunctory manner from a text-book, and the method I suggest would be more dignified and beneficial, especially if physicians were invited in to give many of the talks. By this or some similar device the continuity of the science courses could be preserved.

Botany and zoölogy occupy at present an advantageous position that probably cannot be bettered. I would, however, give two years to each. The second year in botany could be given to systematic and economic botany, preparing the way for agriculture. A good second year's work in zoölogy would be formed by giving a half year to study of insects and economic zoölogy and a half year to vertebrates, with special reference to physiology, including human physiology. There is plenty of work in electricity for more courses in physics. These, however, are mere suggestions of my own. The great need is for careful study of the situation and experimentation with a view to improving not only the organization of the courses but also the methods employed in presenting the various sciences.

No one can justly say that this proposed increase of science would burden the course of study, for we have only to look to the foreign language courses to get a refutation of such a charge. The cost would be but little greater, nothing at all except perhaps in physics and agriculture. The added time for better developed courses and the cutting out of hurry and scrimping will add dignity, interest, and attractiveness to the courses in science and greatly increase their value. It has been found in the past that increased facilities for education always meet a prompt response in increased patronage. So with increased facilities and saner methods would come greater appreciation of science and still greater appreciation of the work the high schools are doing for the people.

ELEMENTARY CHEMISTRY TEACHING AS A MEANS OF DEVELOPING THE POWER OF INDEPENDENT SCIENTIFIC REASONING.[1]

By Arthur A. Blanchard,
Massachusetts Institute of Technology, Boston.

In offering this paper, I am merely putting into words some of my own convictions regarding the ideals to be worked for in the teaching of chemistry. Probably my remarks will contain nothing new or original yet I do not need to make an apology—a teacher's ideals become dulled oftentimes from the routine of inspecting papers and notebooks and many times repeating the same instructions, and that teacher becomes inefficient unless those ideals are frequently freshened. Inspiration is the keynote to success in the teacher's profession, and inspiration comes from having clear cut ideals and bending every effort to attain those ideals. I believe that meetings of the instructors in any one school and still more that meetings like the present of teachers from all over our country are of the greatest advantage in clarifying ideals and affording inspiration.

The title of this paper states what I am coming more and more to believe is the main object to be striven for in the teaching of chemistry. A student's mind is in some senses a storehouse for knowledge, but it would be a waste of good material to fill a storehouse with perishable goods and leave them there until they spoiled. Just so with the facts of chemistry, they are perishable goods—easily forgotten. Therefore I think we do wrong if we regard the student's mind as merely a storehouse. We should regard it rather as a manufacturing establishment which must have its storehouse in which to receive the raw material, that is the facts of chemistry, but which takes this material only as the first step in the production of finished products. The manufacturing process corresponds to the exercise of the student's reasoning powers. Out of what he receives in the unfinished state, he sorts and fits together, that is, he classifies and theorizes.

My own teaching is concerned mostly with students not far advanced in science—the first year students at the Massachusetts Institute of Technology. I think it would be a great mistake to teach these students merely chemical facts and leave the manufacturing of the crude material entirely to the more advanced

[1]Read at meeting of the Section of Chemical Education of the American Chemical Society at Boston, Dec. 30, 1909.

instruction. I do not any more believe that it is the function of the secondary schools to teach mere facts and leave to the colleges to teach how to think. To reason, one must have facts on which to base the reasoning, but I do not believe it is right to teach two facts without bringing out at once some relation that they bear to each other; and the teacher must exert his ingenuity to make the student reason out and appreciate this relation and not learn it simply as he would a third fact.

It is not to be hoped that the secondary schools or even the first year of colleges can complete the process of training the student to be a self-reliant scientific thinker, but they can both make a good beginning, if they will, in teaching the student that he can and must depend on his own reasoning powers, and that isolated chemical facts are of but little importance, except as they are compared with other facts and consistent relations are perceived.

It is a favorite argument among those chemistry teachers who do not believe in teaching such theoretical subjects, as for example, the Electrolytic Dissociation Theory, to beginners in chemistry, that it is illogical to theorize without a sufficient foundation of knowledge. To continue in the line of the previous metaphor, they would consider it unwise to undertake manufacturing operations with only sufficient raw material in the bins to suffice for a short period. Their argument would be unanswerable were it not possible to keep supplying the raw material as rapidly as needed. It would seem to me to be the most economical course to utilize the material as it comes in, and not to lay in a large store which might in the meanwhile sadly deteriorate, before commencing to manufacture.

Now I hope it is not true that because I am an advocate of teaching the electrolytic dissociation theory in first year college instruction that I exaggerate the importance of that or any other theory. My own efforts are to encourage my students to pick out inconsistencies in theories and not to accept the theories until they are satisfied in their own minds that they are consistent and serviceable. I try to make the students see that theories are useful only in correlating and not in shaping facts. Recently I had been pointing out to a class that if all the elements were arranged in a series passing from the most active metal to the most active non-metal that the further apart two elements stood in that series the stronger attraction would exist between them to form a compound. A little later we happened

to be discussing the reducing action of hydrogen peroxide and brought out that one atom of its oxygen attracted an atom of oxygen from permanganate and united with it to form molecular oxygen. I was delighted when one of the boys asked why, as there was no distance between two parts of oxygen in the above named series, there should be any attraction between these parts to form the compound O_2.

In our laboratory we direct that on one page of the notebook the actual facts observed in the experiment are to be recorded. On the opposite page we wish generalizations and theoretical deductions drawn from the actual facts. This distinction seems at first glance to be very easy of comprehension, but one who looks over our laboratory notebooks soon realizes that it is accomplishing a good deal when the student is brought to the point that he appreciates the distinction. To illustrate—a student may think he is stating an observed fact when he says on the observation page that "chlorine has a greater ionization tension than iodine," and he may regard the statement that "the free iodine collects in the globule of chloroform and colors it violet" as a sufficient deduction.

And now to come to the point of how to accomplish the end that the student himself shall think and think on his own initiative. The average student is willing and anxious to learn facts, even to learn theories that are clearly stated to him; but he prefers to learn the latter dogmatically by the same mental process by which he memorizes facts. Self-reliance in other things comes as a result of having overcome obstacles and this truth applies with equal force to the matter of which we are speaking. In order to develop the student's power to think independently we must place obstacles in his way. Quite recently a student came to me with a look of despair on his face and said (he was a foreigner), "You say we study chlorine and you give us a sheet of questions on chlorine; you do not tell me the answers. I do not know them. What shall I do?" Now this student must find out that there is an index in the back of his text-book, and that if his own text-book does not enlighten him enough on any point there are several other excellent text-books on the laboratory shelf, and—what is of even greater importance—that oftentimes he already possesses sufficient knowledge of closely related matters to be able to reason out what it is necessary to know of the point in hand. If necessary, all this can be pointed out to him, but he will be the gainer if he finds it out independently by experience.

Students often complain that they find so many things they cannot understand in their text-books that they become bewildered. The answer to such students is that if they understood everything treated in the book they would not need to study it; that they should be satisfied to understand one point at a time, and understanding one point, should seek to utilize the knowledge thus gained by applying it to solving the next difficulty.

Another complaint is that so many things are stated in the lecture and the text-book that it is impossible to remember them all. The answer to this complaint is: Do not try to remember everything! Pick out for yourselves the things you think are the most fundamental. The probability is that in deciding which are the fundamental facts to strive to retain, an appreciation of the subject will be gained which will render unnecessary any special effort to memorize.

It is a wish often felt by the college chemistry teacher that a text-book existed which treated of just the matters which he wished to take up with his classes. The briefer books are not sufficiently thorough and the more complete treatises cover so many points which it is found necessary to omit, that it becomes very difficult to tell the student what pages or what subjects he is expected to master. The lack of just the right text-book certainly increases the difficulties both of teacher and student; but even this has advantages which may fully compensate. It would hardly develop a self-reliant thinking power in a student to assign him each day definite pages—no more and no less—and allow him to think that with these pages his responsibility ended. No more would it make a mountaineer of a man if he were to ride to the top of a mountain in a plush-seated carriage on a cog railway. By all means let him start on the right trail, and if a map of the mountain exists let him have it for guidance. Then if he reaches the top he acquires confidence in his own strength and in his ability to utilize the knowledge of the way already acquired by others. Our young students are, however, for the most part too weak and inexperienced to make mountain ascents at first without a guide. We must go along with them to see that they do not give up of exhaustion nor fall back from the precipice of difficulty into the gulf of discouragement. We do not want to carry them, nor even to carry their packs for them, but we do want to show them how they can pick out their way and how they can make the best use of their strength.

In summarizing now the idea I have tried to present: It is in brief nothing more than the fundamental principle of scientific education, that the student should be taught to think; but this principle is of such importance and the possibility of losing sight of it is so great when we are endeavoring in a limited time to impart a large amount of seemingly essential information, that I do not think I am wasting time to dwell upon it. Mere knowledge of chemical facts may be of extreme usefulness to the man if he happens to have learned the exact facts that he may happen to require; but the real usefulness of knowledge comes from an appreciation of the meaning of facts and of their relation to other facts. Then the student has at his command not only that which he has laboriously memorized, but a wide range of scientific knowledge. Thus I think every effort of a teacher should be bent to train his students in the habit of real scientific reasoning and to guard against a mechanical learning of the lessons, and I think the process ought to be commenced in the earliest teaching, not, to be sure, by bringing in involved theories, but by always insisting on an appreciation of the simplest relations.

During the Tuesday's session of this section I was greatly interested in the discussion of the secondary school problem, and I believe with the speakers of that day, that the instruction ought to be planned for the pupils who are *not* going to college, rather than to impart to a few men a knowledge of facts sufficient to pass an examination made out on arbitrary lines. The few college candidates may well be left to take care of themselves, and in fact I believe they will get a training to stand them to far better account in their college work if they are not taught with a view of passing an examination. If they have been given merely a specific amount of information, the likelihood is small that there will be enough of it left after a summer's vacation for a college teacher to discover. It is simply astonishing to find men who come to us from some of the best equipped high schools and who have presented us with very nicely written laboratory notebooks, and who yet are apparently ignorant of what we have excellent evidence they have at one time learned. On the other hand men come to us with a very meager previous course, but who naturally have scientific minds, or in whom the habit of scientific thinking has been encouraged, and these men quickly grasp subjects of which they had no previous knowledge.

If a secondary school teacher should ask me what subjects I

thought ought to be included in his course, I should say that he knew the conditions of his problem so much better than I that my opinion would be of but little help. And it is really the method that trains the student, not the specific matter that is taught—it is the teaching how to think and always to think. Teaching how to think does not mean teaching complicated theories; it means rather to start from as simple facts as may be, and teach the student to eliminate complications and perceive the most obvious truths.

An unsystematic accumulation of chemical facts will never do the pupil much service whether or not he goes to the college, but the *power to think* when it is developed will not be lost but will always serve him, whether in a more advanced school or in practical life.

VACATION FOR RECREATION AND EDUCATION.

You are familiar with the famous school established years ago by Louis Agassiz on the Island of Penikese. An account of the opening exercises has been perpetuated in the tender, expressive poem, "The Prayer of Agassiz," by John Greenleaf Whittier.

The Agassiz Association, in honor of that great scientist, is at Sound Beach, Connecticut, continuing, in name and in spirit, the work begun in his school. The second session will begin June 27 and will include courses for the general public and for children, as well as for technical students. Two daughters and a grandson of Louis Agassiz are among the many members interested in the establishment of this school, and in the other work of the Agassiz Association, and have contributed liberally toward defraying the expenses.

President David Starr Jordan of the Leland Stanford Junior University, California, is one of the trustees of the Agassiz Association and dean of the council. President Jordan was a pupil of Louis Agassiz at the Island of Penikese.

The school is established under one very novel condition in that the price of tuition is left for the pupil to decide. The contributions last year ranged from twenty-five cents to one hundred dollars, and the studies that we offered were those easily understood by a kindergartner or by the scientific specialist who came many miles to take special courses.

Further particulars may be obtained by addressing The Agassiz Association, Arcadia, Sound Beach, Connecticut.

THE CASE AGAINST QUALITATIVE LABORATORY EXPERIMENTS IN GENERAL CHEMISTRY.[1]

By Edward Ellery,
Union College.

The introduction to a well-known and excellent scientific treatise in general chemistry bears this statement: "The great importance to the student of himself performing experiments illustrating the preparation and properties of many of the substances treated of in his text-book, cannot well be overestimated. If he be in attendance upon a course of chemical lectures, opportunity should be given him of repeating the simpler experiments he may see performed upon the lecture table; if he be not attending lectures the necessity for such practical work on his part is greater still." The author has in mind the usual qualitative experiments, which do not require definite measurement of any kind. With both alternatives in his statement I take issue. If the student is not attending a course of lectures in general chemistry he cannot perform experiments in the laboratory with any large chance of success; if he is attending such a course, the case against that kind of laboratory practice is as follows:

1. It is a waste of the student's time to merely repeat in the laboratory what has been done in the lecture room, not because he is an awkward workman or uses cruder apparatus, but because he learns nothing new or makes wrong inferences. If he gets accurate results nothing has been added to his knowledge; if he fails to do so, he thinks he has learned that sometimes matter acts as the book states and sometimes it does not. The student is thus cheated of his right to get something new or additional in every hour of the course, and of his right to receive such a presentation of the science that his early impressions will not need later revision, and that correct inferences will be inevitable.

The time element in no course of study is more worthy of consideration than in the course in general chemistry. Students must be given more in these days than twenty years ago, because there is more to be given. Thermal and electrical relations must be dealt with, as well as the synthetic and analytic processes. Some physical chemistry must be taught, and more about the carbon compounds should be included than is the usual practice. Hence not only should more time be given to chemistry than has hitherto been allotted the subject in the ordinary curriculum, but every hour of that time should be very carefully planned.

[1]Read before the section on Chemical Education of the American Chemical Society at Boston, December, 1909.

2. The student is likely to get wrong impressions of the science from his qualitative experiments, or to miss entirely some impressions he should receive. This results from the facts that no great care is required for their performance, because the experiments are not exact, and that, even if performed with great care according to the student's standard, he may not get the results he has been led to expect. No great care is required to get *some* oxygen and even when it is impure its properties may be studied in a kind of way. The careless student may take more or less of the ingredients he is directed to take, may not even weigh them at all, may mix them imperfectly, apply heat roughly, use dirty apparatus, and yet secure a fraction of the correct amount of product. Such a bungler will miss entirely the impression of exactness in the weight relations of the elements to each other in their compounds.

Or, in some instances, the apparent product of the reaction does not show the properties expected. Antimony will not flash fire in the chlorin gas the student generates. His alleged hydrogen is not lighter than air. Sometimes ammonium nitrate gives off a gas that will support combustion and sometimes it does not. Hence he makes the inference that reactions of matter are variable in results.

3. Qualitative experiments do not make for independence. This is especially the case in those laboratories where students work in groups, and it may be true in any case. It is always possible in this kind of laboratory practice for a student to write his notes or sketch his apparatus on the basis of what he has learned in the text or seen on the lecture table. This is to be expected, for he goes to the laboratory after the reaction has been emphasized and the apparatus shown. At best, notebook work of such descriptive character is of questionable value, and the time given to it far from most profitably spent.

4. Painstaking and critical observation is possible in qualitative experiments, but is difficult. Important phenomena may be overlooked or fail to occur, because of hurried work, careless use of materials, or faulty apparatus.

The case against qualitative experiments in general chemistry may be summed up thus: the weightiest pedagogical consideration is that the student learns nothing new from them, and may get wrong impressions, or miss impressions that he should get. The weightiest scientific consideration is that the student learns nothing of the four laws of chemical combination, nothing of

the exactness of the science, nothing of the fact that reactions result from definite conditions.

This is detrimental to the student and to his knowledge of chemistry. There are two classes of students in the beginning course, the one needing a descriptive knowledge of the science, the other a detailed knowledge. Both require the same foundation, the basal stones of which are the four laws of chemical combination. These laws are statements of quantitative relations. Correct and lasting impressions of their exactness must be given, as well as a knowledge of the general reactions of matter. Lectures and quizzes deal sufficiently with those theories of the science which do not readily lend themselves to experimental demonstration; the lecture table experiments, with the preparation and properties of the elements and their compounds; the text-book emphasizes what has been learned from these sources; therefore the time in the laboratory can most advantageously be used to "connect fact with theory and to emphasize by a large number of determinations the quantitative relations." It is self-evident that the qualitative experiments cannot accomplish this result. The quantitative experiments both do this and meet the objections already stated in the case against the former kind. They require exact measurement, definite results, independent work, a notebook that must of necessity be a record of what is done, care in contruction of apparatus, critical and painstaking observation, exactness and definiteness of habit. To the knowledge gained from books, lectures, and quizzes is thus added knowledge of the exact quantitative relations set forth in the laws of chemical combination. The student both gets practice in manipulation of apparatus, and also must construct it well. He handles a chemical problem not as a matter of mathematics but as a matter of fact. The care necessary to secure the required result compels keen observation. The laboratory becomes the place of serious work and the laboratory period a period of study. The student's time is economized to the last degree, for his attention must be concentrated on the experiment, effort is directed at a precise result, and something valuable is acquired that cannot be learned from lecture or text-book.

I know what some of the objections are to an all-quantitative course of laboratory experiments. The experience of the last few years in the chemical laboratory of Union College has shown that the objections are not insurmountable. Quantitative experiments are not beyond the capacity of the beginner. They admit

of gradation, for the variation from theoretical result is easily adapted to the experience of the student.

A second objection has been raised, that the worker is so intent on the precise result that he loses sight of the chemistry of the experiment and may even lose his interest in his work. We have found the contrary to be the case. The addition of a quantitative requirement has, far from distracting the student's attention, made more emphatic the chemistry of the reaction, and has demanded more critical observation. I have seen students watching with intense interest the action of zinc on sulphuric acid, and the physical changes which potassium chlorate undergoes when heated, because they knew that every bubble of gas was essential to the accuracy of their result.

The cost of equipment is not prohibitive. Glassware for quantitative work costs no more than the ware that should be used for qualitative work. Excellent burettes and eudiometers are available at comparatively low cost. Accurate thermometers and barometers are within the means of any laboratory. A good balance, sensitive to a milligram, and enclosed in a glass case, can be imported, duty free, for about $14. Even it equipment were more costly, I would still urge the quantitative course, with a smaller outlay for laboratory furniture. A good balance is more essential to correct teaching of chemistry than the best laboratory locker. A carefully graduated burette rests as well on a wooden top table as on white tile.

A fourth objection to quantitative work for beginners is that the experiments possible of performance are too limited in number and kind, and do not illustrate a sufficient variety of reactions. Prof. J. T. Stoddard's excellent book, "Quantitative Experiments in General Chemistry," is the answer.

The considerations here given do not constitute a contribution of something new to the discussion of the comparative value of qualitative and quantitative experiments in a course in general chemistry, but are the reason for, and results of, the introduction of an all-quantitative course in Union College. The results warrant our recommending the use of quantitative experiments to all teachers of chemistry, whether in secondary schools or colleges. By means of them the student not only receives correct impressions of the science, which need no later revision, and is better prepared for whatever subsequent courses he may pursue in chemistry, but also develops habits of accuracy and definiteness which are of inestimable value in all courses and in any career.

THE SYLLABUS IN GEOMETRY.

A. LATHAM BAKER, PH.D.,

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Of the two extremes in the methods of teaching geometry, the syllabus method and the text-book method, the one is unsatisfactory because of the enormous amount of work demanded of the teacher in the reading and correcting of notebooks, to say nothing of the poor quality of the notes themselves; the other because of the deadening effect of the cut and dried work of the text-book, leading to mere memory work.

The following suggestion is an amalgamation and compromise method by which we can do away with the reading of notebooks by converting the text-book itself into a notebook, and to a large extent enlighten the subject by proceeding independently of the text-book, using it merely as a reference book.

One great trouble with the syllabus methods is that the investigations of the student are not systematic, but rather haphazard. He is given his marshaled theorems and his objective goal, but even with the most enthusiastic syllabist the system is apt to end there; and beyond a blind groping for some theorem which will help him out, the student is rather apt to be in the dark as to *what to do next.*

On the contrary he should have a systematized course of procedure so that instead of wildly groping he can put his finger on a definite operation, to be rejected after trial, perhaps, but yet a definite operation to be tried, some definite procedure which will keep his pencil moving along some clearly defined line of thought.

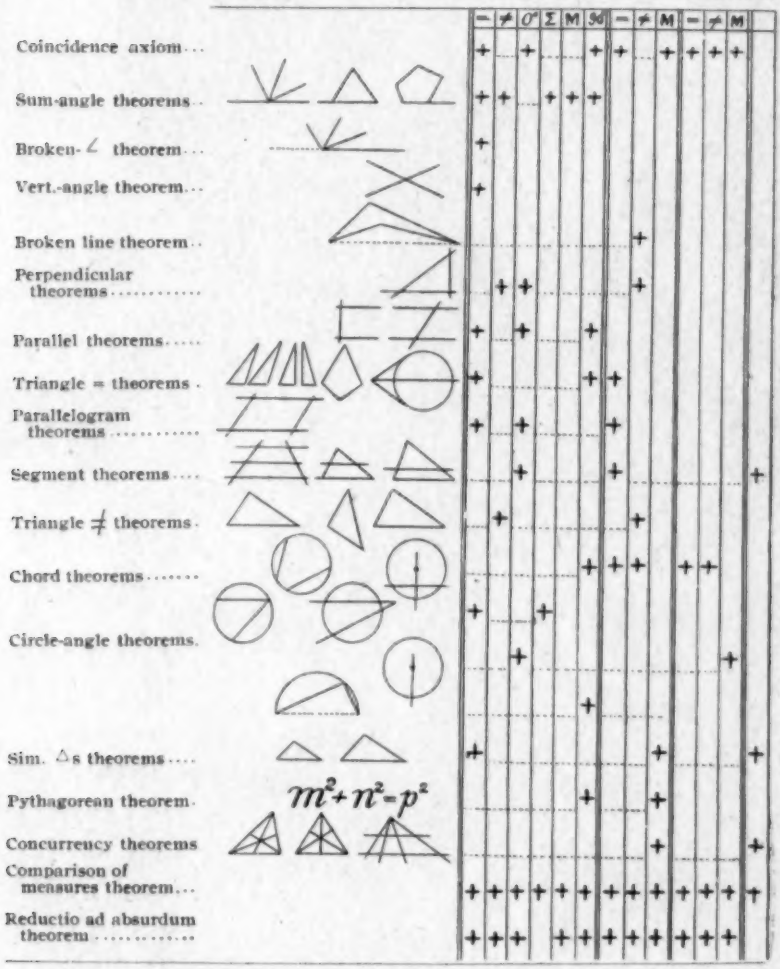
Even in the syllabus method the student is puzzled by the generality of the questions which he is supposed to ask himself: What theorems have we for this, that, or the other thing? What follows, etc, etc.?

Much of the student's difficulty lies in the lack of a clear picture of the different figures previously secured. These figures should be arranged for him. He has neither the skill nor the grasp of the subject to do it for himself.

I suggest the following grouping of theorems and the corresponding diagrams which will be found to be a material help to the memory:

Classification of Theorems and Axioms

Used for Comparison of



Note: — M indicates measure.
Σ indicates summation.

When confronted with a figure as originally given, or after the addition of construction lines, the student should seek the *consequences* flowing from the hypothesis in that diagram, or from the addition of construction lines.

These are most systematically found by means of the 3 F's:

What FIGURE have we?

What FACTS (theorems) about such figures?

What FOLLOWS here, in this particular diagram?

To find "What figure?" run the finger down the list of diagrams until a recognizable figure is found concerning which we have some data or some pertinent designation by letter. Frequently two or more of these recognizable figures will be found, in which case the FACTS (theorems) concerning each figure should be utilized until something is found which is of value in the diagram under consideration. All the recognizable figures and their facts may have to be used, some rejected, perhaps. Often the unrecognized figure will be the one which is the key to the situation. Thus, in the diagram of, "If the two sides of a quadrilateral are equal and parallel, etc.," when the diagonal is drawn for the purpose of getting triangles with which to compare the remaining two sides of the quadrilateral, the student is confronted with useless triangles, because of insufficient parts. But, fortunately, he is confronted with another figure, parallels cut by a transversal, a fact likely to be obscured by the triangles and overlooked by the beginner, except as he runs his finger down the line of diagrams. Having discovered this figure, some one of the parallel theorems supplies a fact which makes the hitherto worthless triangles now usable, and gives a chance to compare the unknown sides of the quadrilateral, as we started out to do.

With this 3 F order of procedure, the student can always do something, if it consists merely in the clerical work of checking up figures to see whether or not they are found in the diagram. He can also hunt up the facts which he knows about such figures.

He can also tabulate the particular results that follow in the diagram under discussion. He can have no excuse for not moving, for there is always something definite to be done, mechanically, perhaps, but as definite as any classification of observed facts can be. It becomes at least an exercise in observation, if nothing more. It is well to have the results which *follow* the facts marked upon the diagram itself, equal angles with the same letter, and so on. Having exhausted the figures of the diagrams and stated the FOLLOWINGS, start over again: What available figure in the diagram, with its facts and followings? The previous results may make a new triangle available, as in the example above. In this way there is no excuse for the dullest student not doing something, tabulation of results, at least, even if unable to draw the inferences from the results.

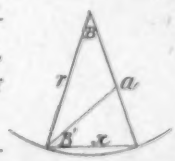
"Education is not receptivity, but activity; not impression, but expression; not learning, but thinking; not knowledge, but power."—*Horne: Philosophy of Education.*

"To describe without rising to the causes and descending to the consequences," as in the current text-books, where nothing more than the verification of the logical chain is called for, "is no more science than merely and simply to relate a fact of which one has been a witness."—*Guyot.*

Aside from the standard pedagogic requirements the student in geometry should have a ***predetermined reason*** for each step; not a reason *postdetermined* by the fact that he has seen it in the book, or that somehow it gives the desired result. A post-determined reason is much like the popular advertisement, "Something grew this hair, and I can prove it;" this step gives an answer and I can prove it.

In the problem, *To inscribe a regular decagon,* the book says, "Draw any radius and divide in extreme and mean ratio," etc. "Why?" asks the student. "Because it succeeds and I can prove it," is the silent answer. In the proposition, *Only one perpendicular,* etc., the book says, "Produce PC to P′ making CP′=CP." Why? The reason is ascertained only after its logical success is shown. In *bisecting an arc,* "draw the chord," etc. The outcome will show why, for this method can be shown to be correct. And so on *ad nauseam.* Says Ufer in his *Pedagogy of Herbart,* "The pupil must know from the beginning what is aimed at if he is to employ his whole energy in the effort of learning." But this knowing what is aimed at can only be secured when the student has a *predetermined reason* for the step. This ***predetermined reason*** can be formed only when the student knows the ***dominant operation,*** that is, the nature of the conclusion he is trying to arrive at, comparison of angles, lines, surfaces, for equality or inequality; the characteristic of the operation which is to dominate, control, and direct his constructive work. With this knowledge he is able to select the proper tool, and having the tool he has the *predetermined reason* for the next step.

Thus, *To inscribe a regular decagon.* The dominant operation is the measurement of the line x, but measurement of lines must be made by similar triangles (or by the Pythag. Th.). Hence:



Draw the radius a to begin the construction of triangles containing the line x.

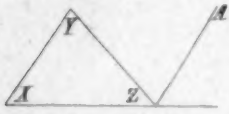
Make $\angle B = \angle B'$ because this construction will always give similar triangles, one of the diagrams we are restricted to.

Marking the values of the angles, and the consequences which (3 F's) flow from them, we find we have (in this case) enough parts of the similar triangles marked to enable us to state a proportion between the sides, viz:

$$\frac{r}{x} = \frac{x}{r - x}$$

which shows that x is the medial segment of the radius; and now we know what to do next and why, predeterminedly.

Proposition: *The sum of the angles of a triangle equals 180°.*



Here the dominant operation is the comparison of the sum of the angles X+Y+Z with a straight angle. But before we can do this we must bring the angles together in order to add them. This transference or bringing together is done by means of the parallel theorem. Hence:

Draw ZA||XY.	For the purpose of getting ||s cut by a transversal so that we can transfer the angles X and Y to the neighborhood of Z.

Problem: *To bisect a given arc.*

Make the chord of the arc the diagonal of some rhombus.	Because the diagonal of a rhombus is bisected perpendicularly by the other diagonal, and a perpendicular bisector of a chord is a bisector of the arc also.

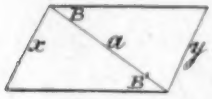
Proposition: *In an isosceles triangle,* etc.

Here the dominant operation is the comparison of two angles for equality, and the most promising tool for such a purpose is the Triangle Theorem. Hence:

Draw a line through the vertex	For the purpose of getting △s containing the base angles.
bisecting the vertical angle.	For the purpose of getting a pair of equal angles in the △s, the two pairs of equal sides being already there.

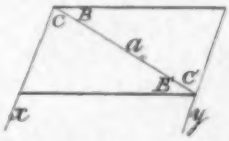
The same apparent line may be drawn for two totally different reasons, thus:

Proposition: *If two sides of a quadrilateral are equal and parallel* | *the other two sides are equal and parallel*
the other two sides are equal and the figure is a parallelogram. | *the other two sides are parallel*



Draw a to get $\triangle$s, because we prove $x=y$ by the $\triangle$ theorem.

$\therefore$ angle B=B'
$\therefore$ $x=y$, $=\triangle$s, etc.
Q. E. D.



Draw a to get a transversal, giving alt. int. angles, because we measure the zero angle between x and y by means of the parallel theorem.

alt. int. angles of ||s are =.
$\therefore$ angle C=C' , $=\triangle$s, etc.
$\therefore$ $x||y$, parallel th.
Q. E. D.

To utilize the text-book as a notebook, we can develop the theorems in the class and refer them to their proper places in the text-book upon completion. By adopting an order different from that of the text-book, the student will be unable to use the text-book as a key; the difference in the methods of demonstration will also hinder this. The current demonstrations of the text-book can be made semioriginals in spirit if not in letter by demanding a specific predetermined PURPOSE for each item of construction, in the triple form of the 3 W's:

WHAT figure is the construction intended to secure?

WHY, for what purpose?

WHEREWITH is this purpose to be accomplished, i. e., by means of what theorem?

The 3 W's give the reasons for the construction, the 3 F's give the consequences which flow from the construction.

Similarly in construction problems, a predetermined general reason for the construction should be demanded, under the heading *General Construction,* to be given in three parts:

WHAT figure are you going to use?

HOW (designating the manner in which it is to be applied to the data)?

WHY (stating why that manner of application will accomplish the purpose)?

After this should follow the specific construction, with its specific details, a reason being given for each detail. Finally proof, showing that the construction has accomplished its purpose.

EXAMPLE: *To bisect a given arc.*

General Construction: Use some rhombus, making the chord of the arc the diagonal, because the diagonals of a rhombus bisect each other perpendicularly, and a line perpendicular to a chord at its midpoint bisects the subtended arc.

Detailed Construction:

With equal radii and centers at the ends of the arcs, draw intersecting arcs.	To get the equal sides and the vertices of some rhombus.
Join the two intersections of the arcs.	To get the other diagonal of the rhombus, the chord being one.
The intersection of this line with the arc is the bisecting point.	
Q. E. F.	
Proof. The line joining the two arc intersections is $\perp$ to the chord at its midpoint.	Diagonals of a rhombus bisect each other perpendicularly, these lines being diagonals of a rhombus by construction.
$\therefore$ The intersection with the arc is the midpoint sought.	A perpendicular to a chord at its midpoint bisects the subtended arc.
Q. E. D.	

In fine, the 3 W's when properly answered insure the students predetermined reason and satisfy Ufer's demand. A student who can give the 3 W's has practically almost completed the demonstration at the threshold. All that remains to do is to try out his reasons to see if he has made a proper selection of tool and process. Instead of assigning propositions to be learned, assign them for the 3 W's. If the student brings back the 3 W's you need not worry about the proposition, he's got that too, and got it clinched in a way that no amount of memorizing without the 3 W's would give. The 3 W's give the student a *modus operandi*, and satisfy Horne's demand. It gives the mentally sluggish student a semi-mechanical line of progress, along which he can do clerical work if nothing more. But the clerical work will probably bring something more. A demand for the 3 W's will convert the text-book into a book of partially solved originals, some problems with answers, some without, and relegate it to the position of a partially written notebook.

SOME CHANGES IN TEACHING GEOMETRY.[1]

WM. A. FRANCIS,
Phillips Exeter Academy.

About a generation ago teachers were disturbed by the fact that the study of geometry did not give all the returns which theory claimed should result from its discipline. In consequence original theorems and problems were inserted in text-books. The effect of this was a material improvement, but the improvement was far from being satisfactory. Then came the introduction of laboratory or heuristic geometry. Great things were prophesied for the invention by its zealous advocates, but we hear little about it to-day in its extreme form. I visited the class of its chief advocate in Massachusetts some years ago, and found that four or five in a class of twenty were doing all the thinking. The others were obviously marking time, and waiting for the pioneers to cut out the path. The most hopeless and despairing of my boys are those who have failed in the use of the heuristic methods.

Within the past ten years much has been done to introduce more concrete methods and to bring things into a more comprehensive form, but we are still far from arriving at agreement about many details. There is at present a great unrest about the teaching of mathematics in secondary schools. This is a promising condition of affairs. The dissatisfaction which we feel is producing many experiments, some of them crude and hard upon the boys and girls, but many of them full of promise, because they are revealing what the minds of children need.

If we ask the student to prove the theorem for the area of the parallelogram and the theorem for the area of the triangle, he will usually give both fairly correctly in rather bad English. If next we ask him to find the ratio of the area of a triangle whose base is $7\frac{1}{2}$ and altitude $3^{3}/_{7}$ to the area of a parallelogram whose base is 30 and whose altitude is 24, he will be quite certain to get an incorrect answer. It is still more certain that he will use wretched methods in combining his numbers.

Conditions at Exeter. We all see the cure for this difficulty, but I fear that we do not use it nearly enough. We are so anxious to have the student grasp the full meaning of the logical system of geometry, we are so occupied in filling him with ideas of reciprocity and laws of converse, that we neglect some of the essentials of his training.

[1] Read before the Association of Mathematical Teachers in New England, March 27, 1909.

We should introduce numerical exercises at every opportunity, using first sixes and sevens, then a's and b's. Every theorem and problem to which numbers can be applied should be used repeatedly for such applications. Complementary and supplementary angles; interior and exterior angles of polygons; angles related to a circle and the arcs which we call their measure; proportional lines; similar areas; the squares of the sides of triangles; areas of regular polygons and circles in various combinations — these furnish endless opportunities for oral and written discipline in numbers. It is easy to find linear and quadratic equations. Chords intersecting in a circle, tangents and secants give copious supplies of quadratics. "Construct a parallelogram equivalent to a given square, having the sum of its base and altitude equal to a given line," and its companion problem are comparatively unimportant as geometry. The only excuse for teaching them is to illustrate geometrically the discriminant of a quadratic equation. Thus used, they give the boy some feeling of the unity of mathematics.

Exercises should be introduced at the right time. In their simple forms they should accompany their appropriate theorems at the first reading. Text-books too often lump them after some group of theorems, or at the end of the book in an ill-arranged form. It is nearly useless for the boy to prove logically that a triangle's area is one half the product of its base and altitude unless he expects to use this truth at once, employing all the number symbols at his command. How many boys really master the equilateral triangle? How many really conquer the right triangle, with the perpendicular upon the hypotenuse from the vertex of the right angle?

Endless repetition is necessary to convince the student that he is not using a great mass of unrelated facts, but rather a few essential principles. He must learn to use his reason more and his memory less. Plato, it is said, enacted the law that the only tools permissible in geometric work are pencil, ruler, and compasses. If we hold too strictly to this limitation, we injure our teaching. It is possible to restrict a student to logical geometric work while using the protractor for making angles, and the T-square and triangles for drawing parallels and perpendiculars. The draughtsman pays little heed to Plato. Is the boy likely to be harmed if he uses the draughtsman's tools and methods in some degree? It is hardly worth while to teach concrete geometry in the upper grades of the grammar school

and the first year of the high school, if when we undertake demonstrative geometry we do not insist that figures shall be well drawn. When a boy undertakes a theorem applying to all triangles, he almost invariably draws an isosceles triangle. He is content when he has drawn a special figure to fit a particular case. Countless errors result from misleading figures.

Concrete geometry is good, but its results do not last unless its methods are continued to some extent throughout the study of geometry. When a student learns that two triangles are equal if two sides and their included angles are equal, he appreciates the truth more fully if he is required to draw a triangle with an angle, say 55°, and the including sides 6.4 cm. and 8 cm. He thus learns that by a scale drawing he can compute unmeasured distances with reasonable accuracy. Problems fitting the boy's experience should be used in the beginning, but he should not be wholly limited to these.

For some time I have given in my examinations problems which required that a figure be carefully and accurately drawn. No explanation or proof was required. Recently I asked the class to make a square having half the area of a given triangle. Ten per cent of the class drew a square having the same area as the triangle, and then made a square with a side one half the side of the first square. A single glance, or a few rough measurements should have shown them their error. This illustrates the statement which Mr. Campbell made some years ago, that a boy of twelve often has better eyes for seeing than a boy of seventeen. Are not our educational methods partly (at least) to blame for this? When we cease to require the boy to draw with accurate measures, do we not help him to forget to use his eyes and common sense?

The first year in the high school should take as mathematical work elementary algebra and concrete geometry. The latter reviews common and decimal fractions, and employs common and metric measures. The second year should continue algebra and begin demonstrative geometry. The two should travel side by side. The third year should review algebra and complete geometry, or at least plane geometry. In the first reading of geometry the student should omit many propositions and everything pertaining to incommensurables. In reviewing geometry, I believe that two thirds of the students should not take the incommensurable case. The other third, or whatever fraction it is, should take incommensurables. This may be done by

dividing classes into sections, or by encouraging the ablest to do voluntary work. In some such way pupils may take work which they can understand, and the most capable will be given enough to do. The greatest danger in the present movement in geometry is the removal of obstacles, which make real demands upon the boy, from the path of pupils quite able to overcome such obstacles. It is a serious pedagogical error to plan a single course in geometry to fit all pupils.

Here we come to the point where the colleges can help us, if they are willing to take a little extra trouble. Personally, I believe that they ought to take a great deal more trouble in making their examinations. It has been rather the fashion in this association to rail at college examinations. Granting their defects, college examinations have had a tremendous influence in improving the teaching of secondary mathematics. Some day we may be able to do without such examinations, but that day is still far ahead. If we wish to make our teaching of geometry more real, if we wish to use numbers more, and require more careful drawing, the college examinations must help us. They must contain problems of every kind worth teaching at all.

Colleges should examine in geometry by two methods, one more concrete than that used at present, the other even a little harder than at present. The concrete paper should call for formal proofs of only the simplest and most important facts. It should have much computation. It should have at least one question requiring careful drawing. This should be made on special paper, and should be large enough to ensure accuracy in measurement. Drawings of loci, without proof, could furnish material. The mean proportional for the construction of triangles and squares of a given area, or a fraction or a multiple of a given polygon should be employed. An irregular polygon could be constructed with given sides and angles, and its areas approximately found by dividing it into triangles. Questions could be given like: Construct a regular hexagon whose area shall be as nearly as possible 100 square centimeters; a circle whose circumference is 60 cm.; a circle whose area is 75 sq. cm. Dozens of such questions, as easy or as difficult as desired, can be made. A student passing such an examination would be quite as well fitted as the average student of to-day, and should have at least a shade more common sense in dealing with geometric figures.

The less concrete paper should demand more of the logical and less of the computation idea; it should have one question on incommensurables; it should demand a little more geometric power than the average paper of to-day. Probably only ten to twenty per cent of the students would try such a paper. The question at once arises whether it is worth while to make a paper for so few. The colleges should not encourage secondary schools in their present error of fitting, or trying to fit, all minds to a single course. The best minds should be exercised fully. At present we confuse the slowest and only half discipline the brightest of our pupils. We are at present trying to fly with plough-horses, and to plough with Pegasus.

Since one paper would call for greater power than the other, it should be the honor examination and the other the pass examination. The colleges may well go further still and give a higher rating for one paper than the other. The present is a good time to change. There is a rumor that Harvard may make such a change in language examinations. The student securing a pass may receive, say, four points; another receiving an honor grade may be credited with six points. I believe that much good may grow out of some such change. The college must regulate the details, but we can all advocate the principle, if we believe that it will improve present conditions.

To sum up:

We are not satisfied with our meager returns from the study of geometry.

Too much emphasis has been given to the logical, too little to the practical side of geometry.

We must make geometry more concrete, bringing into it much more number work.

We must have better drawing, and more drawing to scale.

We must not neglect the best and poorest scholars.

The colleges should fit their examinations to the students.

We may divide students into two unequal classes: those having a ready perception of geometric facts, and those who must struggle hard for what they acquire.

The colleges should recognize this, and give two methods of passing geometry. If one method requires more power than the other, it should have a higher rating.

For the Pass requirement—

Omit incommensurables entirely.

Omit most of maxima and minima.

Omit most of the originals which require demonstration, keeping only the simpler and more important.

Omit the computation of π; have the student know $2\pi r$ and πr^2 without memorizing proofs; but have him know the plan of proofs.

Add more problems of computation on complementary and supplementary angles; sum of the angles of triangles, polygons, etc.; measures of angles; similar figures; areas of polygons and circles.

Add scale drawings for equal triangles and polygons; for similar figures; for areas; for transforming figures to other figures, etc.; loci (without proof).

Add problems which will demand linear and quadratic equations in simple forms.

For the Honor requirement—

All included in the pass requirement.

Incommensurables and limits.

Proofs of loci.

Harder original theorems.

The honor examination should be given a higher rating than the pass examination.

At the close of the discussion of Mr. Francis's paper which is printed on the preceding pages, Professor Julian Coolidge made the following reply to some strictures on the character of Harvard examination papers in mathematics.

A few years ago I was dining at the house of a distinguished professor of mathematics, a cousin of Madame Alfred Dreyfus. The conversation turned upon the Dreyfus affair, and became quite animated, although nothing in particular was being done about the case at that time. Dreyfus had been pardoned and was at liberty. The lady of the house leaned over to me and said: "We try sometimes to get off this subject, but we never succeed for long." I think you all see the application. Some of us college men feel, in coming to the meetings of this association, as if we were to be butchered to make a Roman holiday.

Perhaps you school men take this way of paying us back for what we do to your pupils in the entrance examinations.

At Harvard each member of the Division of Mathematics inspects all the entrance examination papers, so that we are all, in a way, responsible. As a matter of fact, the man who makes out the papers is the most responsible, and I am that

man; at least, in the case of geometry papers. I am even responsible for the mirror locus problem which has been so much criticised. Our late president, Mr. Meserve, wrote me, asking me to address the association on the subject of loci. He said that anyone who could write a question like that must have original ideas about loci. I wisely declined. That particular problem did not seem to me to be very hard. The proof is, as you see, very short. (*Proof given.*)

I am much in sympathy with what Mr. Francis has said about combining problems in algebra and geometry. It is, however, discouraging work. The boys do not appreciate it. Very few boys cared for that problem which Mr. Francis commended about the most distant point of a circle. Again, in making out the paper in advanced algebra last year, I was looking for a problem in permutations and combinations. I was tired of the sort of problems which asks how many signals can be made with a certain number of colored flags, or how many words can be made from the letters x, y, z, each combination of letters being considered a word; so I asked what would be the greatest number of possible intersections of 77 circles. I thought that a pupil would realize that in order to have an intersection, you must have two circles, the number of combinations in 77 is $\frac{77\times 76}{2}$, but as each pair of circles must cut twice, the number of intersections would be 77×76. It did not seem to me a very difficult problem, but few of the candidates tried it.

I am strongly in favor of the movement to bring algebra and geometry into closer relation. Pupils should not study algebra for a year, then geometry for a year, but should alternate often. The relations of the two subjects should be insisted upon. A certain amount of time lost in duplication might thus be avoided. I have a belief also that the subject of trigonometry might be dissolved into algebra and geometry. How easy it is in studying similar triangles to introduce the subject of sine and cosine. How much more satisfactory the law of cosines is than the stupid proposition which says that the square of one side of a triangle is equal to the sum of the squares of the other two minus twice the product of one of these sides multiplied by the projection of the other upon it. As for the trigonometric identities, they might be introduced into algebra with quadratic equations. How those dreary chapters on radicals and the theory of exponents would be enlivened by learning the theory and practice of logarithms!

WHAT IS A RATIO?[1]

By Professor Julian L. Coolidge.
Harvard University, Cambridge.

I do not know what a ratio is, but I want to learn. I asked my pupils in solid geometry, but their replies were too contradictory to be of service to me. In view of this condition, it is interesting to note that Laisant's book, "Les Mathématiques," recommends that ratio should be introduced as soon as number. This view has also the sanction of Newton.

When we begin the study of algebra, we take up monomials and polynomials, addition, subtraction, multiplication, and division, easy equations, elimination, and so on; and we come to fractions, and fractions are hard. But though they are hard, there is no metaphysical difficulty. We understand what fractions are, even though we find them hard to manipulate.

On the other hand, when studying geometry, after passing through the first two books and dealing with matter that is apparently germane to the subject, we come, in the third book, upon a long interlude regarding proportion, full of long words. This takes a lot of time. Is it algebra? If it is algebra, why this hard way of doing easy problems in fractions? I remember when I was studying the subject myself, that I was much puzzled by this question, and I concluded that the mysterious thing about it was the knowledge of ratio which the writer of the book seemed to possess, but which had eluded me. Years later, inspired by Hamilton, I adopted the definition that ratio was the operation which would convert the second term into the first, and I even went so far as to write this sample of a ratio:

$$\textit{Chicken} : \textit{egg} = \textit{hatch}.$$

Our text-books are prone to say that ratio may be expressed as a fraction. Why not say that a ratio is a fraction? There are some complications that seem to prevent that definition. In the first place, our inheritance from Euclid, who uses the concept of equal ratios in his treatment of similar figures. As he uses the word, it does not seem to mean a fraction. I have the greatest respect for Euclid's treatment of proportion; it is a monument of human reason, and furnishes rigorous proofs of the theorems with which it deals, without resorting to the incommensurable hypothesis. Our experience, however, has conclusively shown that Euclid's treatment is not teachable.

[1]Read before the Association of Mathematical Teachers in New England, December 5, 1908.

The second impediment that complicates our use of the word ratio is confusion as to the meaning of the things that we are comparing. In geometry we continually use the same word in different senses. For example, the word "line" may mean a curved or a straight line; and if we restrict it to "straight line," it may mean the points in an indefinite straight line extending without stop in both directions; or it may mean the points that are in a line beginning at a certain point and extending indefinitely in one direction; or it may mean the points that are included between two end points; or it may mean the number of length units that are contained in a certain specified straight line. This ambiguity occurs in our use of letters and of symbols. For example, we have two rectangles with altitudes a and a' and with bases b and b', and the rectangle could be represented by R' and R'. Then we proceed into an argument in regard to these rectangles, in which we use a and a', b and b', etc., as if they were algebraic letters representing numbers. I suppose that our first intention in giving a name to these lines was just the same as when we give a name to a person. We might say, for example, that a and a' would stand for Araminta and Arabella, and b and b' would stand for Belial and Beelzebub, or any other names that we might find appropriate. With that hypothesis, it would be a little difficult for the pupil to guess just what was meant when we multiply Araminta by Belial, or Arabella by Beelzebub, and why any of them, or all of them, should cancel.

Of course you understand that if we were pupils of Halsted's, we should deal with this matter in a strictly logical way, under the regulations of the sect calculus. I do not know whether it would be quite proper, in these liberal days, to have anything to do with the sect calculus in the public schools. It might be disapproved by the school board.

Now that I have made my diagnosis complete by specifying these two causes of confusion, I will make my own suggestion as to the remedy. It seems to me that the pupils should have a clear notion of the process of measurement. If they have observational geometry in the preparatory work, that would be a part of their experience on which they could rely in geometrical study; but anyhow, it is not a difficult matter. With this premise, the ratio of two lines is the fraction formed by taking the length number of one line and dividing it by the length number of another line, and so for the ratio of any two comparable objects. It would be worth while to say at this point that there are two

or three algebraic manipulations that would be useful, and show them in half a page, and then use them; and it would be instructive to consider the effect of changing the unit of measurement, and note how that will effect ratio. In particular, take the second term as unit; the ratio is then the measure of the first in terms of the second.

The pupil cannot deal with irrational ratios until you have told him how to measure a quantity incommensurable with the unit. I think it would pay to have algebra and geometry converge to this point at the same time, so that the irrational numbers—the square root of two, for example—could appear in geometry at the same time that the algebra class was trying to deal with such numbers in its domain. Let us say that a pupil makes a succession of guesses at the square root of 2. The first guess would be 1—too small; the next would be 1.4, the next 1.41, the next 1.414, and so on. I think for a class beginning this subject it would be desirable to express the situation somewhat like this These are numbers struggling toward an ideal. This ideal is a number whose square is two. They never get there. Illustrate this geometrically, by the attempt to measure the diagonal of a square in terms of a side. If you ask me what that ideal is, I can only reply that it is what these fallible numbers are striving for; that is to say, if you corner me arithmetically, I cannot tell you. All we have, as a matter of fact, is the series of numbers. You will find Hadamard's Geometry interesting on this point, especially in its reference to Tannery, who has the easiest discussion of this difficult subject.

We shall have to take on faith that we can combine these incommensurable numbers as we do ordinary numbers. We must also accept without proof that the ideal sought by a series of fractions is the quotient of the ideals of numerators and denominators.

How does all this apply to ratios? Let us try to show that two rectangles with equal bases are to each other as their altitudes. Take the second altitude as the unit of length, the second area as the unit of area; this will not affect either ratio. Then we have a series of numbers which at the same time represent our attempts to measure one altitude in terms of the other, and our attempt to measure one area in terms of the other. The ideal which these numbers are striving for will be the ratio of the altitudes, and also the ratio of the areas.

This method, without being absolutely rigorous, is well in advance of the traditional one, and does not seem to be any more difficult. Moreover, is it not a real gain to be free from all the troubles attendant on that ridiculous old theorem, "If two variables are constantly equal as each approaches its limit, the limits are equal"?

DISCUSSION.

Professor Osgood said that he could not agree with Professor Coolidge in the view that the existence of incommensurable numbers in arithmetic should be brought into connection with the incommensurable case in geometry. The idea of the scale, of a complete set of numbers, in terms of which continuous quantities like arcs and angles and areas can be measured, is one with which the pupil has long since been familiar, and this idea should be presupposed in geometry. Thus each of the quantities whose ratios are to be treated has a numerical measure, and the geometric proposition relates to the equality of two pairs of ratios of numbers and hence asserts that one number is equal to another. In the equation or proportion,

$$\frac{\text{arc } AB}{\text{arc } AC} = \frac{\text{angle } AOB}{\text{angle } AOC}$$

that we find in the geometries each one of the four members is a number, the numerical measure of the geometrical quantity in question, and the equation asserts the equality of the two numbers, namely, the ratio on the left and the ratio on the right.

The incommensurable case is a fact of mathematics. Its treatment need not, however, be made burdensome by introducing difficulties that the pupil would never be troubled with if they were not forced on him in the instruction.

An experiment which is being tried on the Hudson and Manhattan Railroad tunnel system beneath the Hudson River will be watched with much interest by both the railroads and the public. It consists in illuminated station signs, placed inside the cars, which are so arranged that the guard, by pressing a button when the train starts, rings a bell and causes the sign to display the name of the next station. This sign continues to be displayed until the train leaves the station designated. A simple device, this, whose utility is so obvious that it should have been in use from the very commencement of electrically operated rapid transit.

THE FACTS ABOUT PERRY AND HIS IDEA.[1]

By John C. Packard,
Brookline, Mass.

Professor John Perry, M.E., D.Sc., F.R.S., author of a number of widely known books upon the subjects of mathematics and physics, is Professor of Mechanics and Mathematics in the Royal College of Science, South Kensington, London S. W., and, at last accounts, was acting as Chief Examiner in Engineering for Technical Schools, Art Schools, Evening Schools, and Other Forms of Provision of Further Education in England and Wales under the direction of His Majesty's Board of Education.

His idea is that the subject of mathematics as presented to students in the vast majority of schools and colleges throughout the civilized world has been made far too abstract, too complicated, too academic, and as a consequence has been kept too far removed from the field of its legitimate applications in the world of science and industry. Boys who should be already using logarithms, slide rules, trigonometrical formulas, integrals and the like freely, are found to be still poring over unnecessary details, useless repetitions, impractical problems, and effete material under such headings as elementary algebra, plane and solid geometry, and trigonometry. This is all wrong. Short cuts to practical methods, leading to the rapid acquisition of facility in the use of mathematics as a useful tool, should be the principal end in view and not "mathematical rigor" nor "mental training" *per se*. In the professor's own words, "To me mathematics is a powerful weapon with which to unlock the mysteries of nature. If a man knows how to use the weapon that is enough. Let him leave to others, the men who delight in that, the forging of the weapon, the complete study of it. If I can use the weapon let my study be of another kind—I think, perhaps, of a higher kind—to study the secrets which even an unskillful use of the weapon will reveal to me. Fain would I know more about how the weapon was made and how to forge it for myself; but if I have no delight or skill in making weapons, and if I have uncommon delight in using them, then I will use them if I can, and practice using them till I become skillful in their use." Again, "I believe that men who teach demonstrative geometry and orthodox mathematics generally are not only destroying what power to think already exists

[1] From an address before the Association of Mathematical Teachers in New England, March 27, 1909.

but are producing a dislike, a hatred, for all kinds of computation and therefore for all scientific study of nature, and are doing incalculable harm." And, in another place, "As examples of methods necessary even in the most elementary study of nature I may mention: the use of logarithms in computation, knowledge of and power to manipulate algebraic formulae, the use of squared paper, the methods of the calculus. Dexterity in all these (when properly taught) is easily learned by all young boys. In such practice their brain power develops quite rapidly and they learn with pleasure."

For further literature upon the subject and a complete exposition of the idea, see:

Sundry Articles in Science and the School Journal (Macmillan).
Practical Mathematics, being a Summary of Six Lectures to Working Men. Perry, 1899. Wyman & Sons, Fetter Lane, London, E. C. 6d.
The Teaching of Mathematics. Perry. Paper read before B. A. A. S. at Glasgow, 1901, with Discussion and Report of Committee. Macmillan.

Just about a year ago the writer had the rare privilege of an interview with the subject of this paper, at his headquarters in London, and was permitted for nearly two hours to discuss the teaching of practical mathematics with a "man who knows."

Short of stature, thick-set, with keen eyes, iron-gray hair, a short mustache, smooth chin, a quick, nervous air and a habit of running his hands rapidly through his short, curly locks when thinking earnestly, Professor Perry reminds one of the familiar picture of Beethoven sitting in his study. He is a *live wire;* there is no doubt about that. Book after book and pamphlet after pamphlet are drawn from bookcase, table, cupboard, drawer, to illustrate the meaning and purpose of the new movement in mathematics. The distinguished author believes in his own idea, *that's sure.* To the question as to where copies of the books and papers referred to could be had came the instant reply: "I will send these to your American address, prepaid." "Saxelby's book covers all that any engineer, or anybody else, for that matter, needs to know about mathematics. Geometry, plane and solid, as a distinct subject has no place in undergraduate work, but is adapted only to postgraduate study—a severe exercise—pure logic." "Much of formal algebra should be expunged, thus leaving room for more important topics of applied mathematics." "Teach the pupil, not the subject." "I judge my students by their eyes; when I see that their interest begins to flag I immediately change the topic or the method. They must be kept wide awake at all times."

One cannot quote with precision from such an interview. The memory of it is like that of a fresh breeze from off the hills.

Next to the master stands Mr. Frank Castle, for a long time instructor in applied mathematics under Perry, now devoting his entire time to the writing of text-books in mathematics. He is a genius himself. His laboratory is a model for compactness, abundance of practical exercises and display of commercial apparatus.

So much for the new movement and the man who started it. What has been the outcome? Conservative England with its traditions of a thousand years based in part upon classical Oxford and scholarly Cambridge could be trusted to go slowly in such a revolutionary matter. The notions of centuries are not easily overturned. Throughout the British Isles to-day, however, are to be found two parallel courses in mathematics, one styled pure mathematics and the other practical mathematics. For entrance to many polytechnic, art, and industrial schools the latter is given the decided preference and is rapidly gaining in favor. Five thousand copies of Saxelby's book (see below) have been sold in England alone. The geometry of the preparatory schools has been transformed. All courses now begin with concrete work, using ruler and compasses. The university examiners all recognize the new forms and seldom ask for demonstration of a stated proposition. One cannot fail to see that a revolution is in progress. The publishers have swung into line and are steadily producing a new type of text-book in mathematics. The list here given represents a complete sequence from grammar grades to technology diploma. One must acknowledge that these modern books are at least very suggestive:

TEXT-BOOKS.

Elementary:

Longman's Practical Arithmetics,
Teachers Series, Knowles & Howard,
Pub. by Longmans Green & Co.
Practical Mathematics for Beginners,
Frank Castle, Pub. by Macmillan, 2s. 6d.

or

Practical Mathematics,
Consterdine & Barnes,
Pub. by John Murray, Albemarle St., London, W., 2s. 6d.

More Advanced:

Introduction to Practical Mathematics,
F. M. Saxelby, Longmans, $.80
A Course in Practical Mathematics,
Saxelby, Longmans, $2.25

Many others might be added, for instance:
Practical Mathematics,
Cracknell, Longmans, $1.10
Workshop Mathematics,
Castle, Longmans
In two parts, 1s. 6d. each part.
Calculus for Engineers,
Perry, Macmillan, $2.50

Says Professor David Eugene Smith of Columbia in reference to a similar movement just beginning in our own country, "It is not improbable that the present agitation in the development of preparatory mathematics in this country will penetrate even into our colleges and stir up some new life. When this is done, America will begin to develop for all its schools what England is developing for its technical institutions, books of the spirit of Mr. Saxelby's suited to the peculiar conditions and needs of our country."

May the time speedily come.

AN EXPERIMENT TO DETERMINE THE INDEX OF REFRACTION OF WATER.

By S. H. Anderson,
Occidental College, Los Angeles, Cal.

No claim is made for originality in presenting this experiment. It has these advantages: 1st, in the use of a glass prism in determining the index of refraction the distances used are of necessity small, so that a very minute error in "sighting lines" will produce a considerable error in the final result, while in using a jar of water the same error in "sighting" will result in an error of only about one-third or one-fourth as much as with the glass prism, since the distance with water can be taken three or four times as large as with a prism; 2nd, many laboratories may not have enough prisms of the right kind for this experiment, while nearly every laboratory has the apparatus which is needed for determining the index of refraction of water, or if the apparatus is not on hand it can be supplied at a very small cost.

The apparatus needed consists of a battery jar, 6x8 inches, pins, a pair of dividers, a metric rule, and a board of soft wood half an inch thick.

Fill the jar nearly full of water. Place the board in the jar and hold it down, so that its position is firm and steady. Stick two pins into the board, perpendicular to it, just on level with the surface of the water. You can tell when you have the pins just at the surface by the fact that the water will curve up to touch the under side of the pins but will not cover any part of them. Great care should be exercised in placing these pins just at the water surface for this is a likely source of error. Remove the board from the water and see that the pins are pushed in firmly and perpendicularly. With a fine pointed pencil draw a light line connecting the two pins, and at a point on this line about the middle of the board erect a perpendicular and extend above and below the line. On this perpendicular place a pin P about 12 cm. below AA′. About 2 cm. above AA′ and along a line parallel to it measure a distance 4 cm. to the right of P*r* and place the pin B, and 4 cm. to the left place the pin D. Place the board in the jar of water again and see to it that the water is at the level of the pins AA′ when it is pressed down firmly. Place a pin C so that it seems to be in line with B and P. In like manner place a pin E in line with D and P. Remove the board; see that all pins are pushed in firmly and perpendicularly; wipe off the water; and transfer the positions of the pins to a piece of paper by pushing the sheet down over the pins and drawing lines connecting AA′, P*r*, CB, ED, extending CB and ED until they cut the line P*r*. Call the point of intersection P′. It is the point from which the light waves seem to come when P is viewed through the water and air. (Actually they come from P.) Draw PF and PH. With the dividers draw the arc F*s*′H with P′ as a center and P′H as a radius. This will represent the front of the wave as it emerges from the water. Draw the arc F*s*H with P as a center and PH as a radius. This would be the position of the wave front if there were no change in speed in passing from the water to the air.

rs may be considered the distance that light travels in water in a very small interval of time. If light travels in air faster than in water the portion of the wave front at *r* which emerges from the water first will travel a distance greater than *rs* in the same small interval of time so that it will be at *s*′ when the parts of the wave near F and H are just emerging from the water. Since the actual position of the wave front is the arc H*s*′F with the center of the circle of which it is a part at P′ this experiment shows us that light travels faster in air than in water.

The index of refraction of a substance is defined as the ratio between the speed of light in air and in that substance. So $\frac{rs'}{rs}$ gives us the index of refraction of water. But the distances rs' and rs are so small that they cannot be measured with any degree of accuracy. However $\frac{rs'}{rs} = \frac{PH}{P'H}$, the inverse ratio of the radii of the circles, and the distances PH and P'H can be measured quite accurately. This above equation can be shown to be true by methods of geometry and trigonometry within the limits of experimental error. But the reasonableness of it can be presented to the student without going into the mathematical derivation. The curvature of an arc is rigidly defined as the reciprocal of the radius. But it is evident that rs is a measure of the curvature of the arc HsF, that is, it shows how much the arc departs from the straight line HrF; likewise rs' shows the curvature of the arc Hs'F. Therefore $\frac{rs'}{rs} = \frac{\frac{1}{P'H}}{\frac{1}{PH}}$, or $\frac{rs'}{rs} = \frac{PH}{P'H}$

So by dividing the distance PH by P'H the index of refraction can be found, i. e., the number of times faster light travels in air than in water.

In performing the experiment each student made two trials, and more if the results were not satisfactory; but in nearly every case the error was of the order of one per cent or less. In the second trial the pins B and D were placed at different points, for example, 3 cm. either side of the perpendicular Pr.

This experiment is similar to the method of determining the index of refraction by the ratio of the sines of the angles incidence and refraction in that the apparatus is the same and the method of procedure is the same, but it has the advantage of presenting to the pupil the method of propagation of light, and of giving a clear idea of index of refraction and the cause of refraction, while to the average high school student the "ratio of the sines" means little or nothing and all he learns is that the index of refraction for water is 1.33.

AN IMPORTANT OPTICAL EXPERIMENT.

E. J. RENDTORFF,
Lake Forest Academy, Lake Forest, Ill.

In the laboratory work in optics it is customary to have our students measure the index of refraction of glass and the principal focal length of lenses, by one or more methods. The student soon discovers that the focal length of a lens depends upon the index of refraction of the glass and the radii of curvature of its faces, but the exact relation of these is seldom presented, either in class or the laboratory. The relation is too important to neglect, as we unfortunately are in the habit of doing with an almost unlimited, important and fascinating series of simple optical phenomena. The chief reason for this seems to be a matter of habit.

If F represents the principal focal length of a convex lens, R_1 and R_2 the radii of curvature of its faces and N the index of refraction of the material of which the lens is made, then:

$$\frac{1}{F} = \left(N - 1\right)\left(\frac{1}{R_1} + \frac{1}{R_2}\right) \cdots\cdots\cdots (1)$$

If three of the four variables are known the fourth can be calculated.

As preliminary work, aiding in the understanding of Eq. (1) it is advisable to assign definite values to N, R_1 and R_2 and let the student calculate the value of F. For example, if the index of refraction of crown glass is 1.52, what will be the principal focal length of a lens the radii of curvature of whose faces are respectively 10 and 15 cm.?

In the laboratory Eq. (1) can perhaps best be utilized in determining the index of refraction of the glass of which the lens is made. This solution involves the measurement of F, R_1 and R_2, all of which are fundamental and important. In these determinations the teacher has the choice of half a dozen different methods, thus thoroughly reviewing some of the previous experiments.

For the measurement of F he could employ:

1. The direct sunlight method.
2. The conjugate focii method, where $\frac{1}{F} = \frac{1}{F_1} + \frac{1}{F_2}$
3. Parallax method with the image of a distant object.
4. Bessel's method.

5 and 6. Either of the two telescope methods presented in my article, "The Use of the Telescope in Experimental Optics"

in the June, 1908, number of SCHOOL SCIENCE AND MATHEMATICS.

For the measurement of the radii of curvature, R_1 and R_2, three good methods are:

1. Spherometer method.
2. Using the faces of the lens as ordinary convex mirrors.
3. The method following:

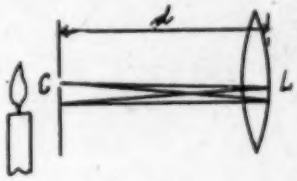


Fig. I.

Illuminate a cross hair, C, Fig. 1, on a metal diaphragm. Move the lens, L, until the image of the cross hairs falls on the diaphragm itself. If d represents the distance from the cross hairs to the farther side of the lens, its radius of curvature is calculated from:

$$\frac{1}{R_1} = \frac{1}{d} - \frac{1}{F} \quad \ldots\ldots\ldots (2)$$

Turn the lens around and calculate R_2 for the other face.

Now substitute F, R_1 and R_2 in Eq. (1) and calculate the index of refraction of the glass of the lens.

For measuring F method 2 would be the most suggestive as it shows the important relation between the principal and the conjugate focal lengths of a lens.

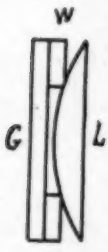


Fig. II.

Another important variation of this experiment is the calculation of the index of refraction of a liquid. In the second illustration G represents a plane piece of glass having a rubber washer, W, cemented on its face. Hold the glass horizontally, fill with some liquid, say water, place any convex lens, L, over it and then hold in a suitable adaptor or clamp.

One of the many optical relations we like to neglect is that of the combination of two or more lenses. It is very simple and should be presented in all classes.

$$\frac{1}{F_{\text{Combination}}} = \frac{1}{F_{\text{Of one lens}}} \pm \frac{1}{F_{\text{Of the other lens}}} \quad \ldots\ldots\ldots (3)$$

The + sign is used if the lenses are additive, viz., both of the same curvature, say convex, while the — sign is employed when the second lens is concave.

In our specified case the water lens is concave, so that Eq. (3) can be written

$$\frac{1}{F_{\text{Water lens}}} = \frac{1}{F_{\text{Convex lens}}} - \frac{1}{F_{\text{Combination}}} \quad \ldots\ldots\ldots (4)$$

Measure the focal length of the combination and of the glass lens alone and then calculate that of the water lens from Eq. (4).

The water lens has the same radii of curvature as the adjacent glass, which can be calculated as mentioned previously. For the plane face R_2 is ∞ and $\frac{1}{R_2} = 0$. From Eq. (1) the index of refraction of the water can now be calculated.

These experiments are not preliminary, but fundamental. They bring to the student the important relations:

1st. Of the principal and conjugate focal lengths of a lens.

2nd. Of the combination of a system of lenses.

3rd. Of the relation of the index of refraction of the material, the radii of curvature and the principal focal length.

With the proper instruction the experiment is easily within the ability of any average secondary school student.

It may not be generally known that Chicago possesses the largest turbine engine generating plant in the world. The Fiske steel power plant of the Commonwealth Edison Company has a capacity of over 150,000 horse power of electrical energy.

A German bird fancier has made a series of experiments for the purpose of determining the vitality of eggs in different stages of incubation. On the fifth day of incubation five canary bird's eggs were taken from the nest, marked with numbers, and replaced in the nest, one by one, at half-hour intervals. This experiment was repeated ten times, with as many clutches of eggs. As a rule, the first three eggs replaced hatched normally and the two others failed to hatch. Hence it may be inferred that the average longevity of a canary bird's eggs, taken from the nest on the fifth day of incubation, is 1½ hours. In the same way the longevity was found to increase to 2 or 2½ hours on the seventh day, and 3½ to 4 hours on the ninth day of incubation. It was discovered by accident that eggs in a very advanced state of incubation can endure very much longer periods of removal from the nest. Two eggs, purchased as plover's eggs, in the course of an excursion, were stowed in a basket, brought home and forgotten. On the evening of the following day a faint "peep" recalled the existence of the eggs, and it was found that a young snipe had issued from one of them. The second snipe soon made its appearance, but lived only an hour. Hence it appears that the vitality of partly hatched eggs depends on the size of the bird as well as on the stage of incubation.—*Science Monthly.*

THE ELECTRIC ARC.

By John A. Hodge,
Scribner High School, New Albany, Ind.

Last summer the writer had occasion to make a review of recent researches on the electric arc. After writing the results of this investigation it seemed that it would not be out of place to present them to the readers of School Science and Mathematics.

The writer does not lay any claim upon a complete review of the arc, but wishes to present simply the results obtainable from sources of information accessible at the time the paper was written.

The electric arc, ever since its discovery by Davy in 1810, has been the object of spasmodic investigations. In recent years the purpose of these has been to verify the various theories that have been presented to show the nature of the arc, as well as to increase its efficiency as a light producer. It is the work spent upon the theory of the arc that I wish to present in this review.

At first thought the arc may appear to be a simple phenomenon; but when we consider in how many ways it may be varied—by using different electrodes, current strengths, different media through which it may take place, variable pressures, and injecting salts of various kinds into it, and then considering that each of these conditions has its own characteristics, there is no wonder that investigators, although they have learned much concerning its practical points, have not yet reached very definite conclusions as to what is really going on in the arc itself and the space immediately surrounding it.

In 1898 N. H. Brown succeeded in photographing the arc produced by an alternating current. This was done by rapidly rotating the film and obtaining a lengthened picture of the arc, which showed two light fronts. The one from the cathode started sooner than the one from the anode, but it moved much more slowly than did the latter. Of course this at once started speculation as to the cause.

It was while studying the results of these photographs that C. D. Child of Colgate University was led to the conclusion that the current, in part at least, was carried by ions—positive ions traveling to the cathode and negative ions to the anode. To explain some of the characteristics of the arc, he assumed the

positive ions to have the faster rate of travel. Both of these statements are only assumptions derived from the photographs of Brown which showed that there is a movement of some sort from the anode to the cathode and vice versa. These light fronts seemed also to move with a variable speed and that just where the positive moved most slowly the negative gained in speed. If we are justified in assuming ions, and of these, the positive to move the faster, by this assumption some of the phenomena of the arc ought to be explained.

We know that there is a greater fall in potential at the electrodes when compared with the fall between the carbons. We also know that the resistance of the arc is not altogether ohmic. It is often said that there is a back electromotive force due to the Thompson and Peltier effects, but it cannot be detected when the current is turned off, even though the conditions for its detection are of sufficient duration. There may be some cause similar to the Thompson effect, but just what it is is not yet known. Will ion carriers of electricity explain any of these things happening in the arc?

Suppose intense heat causes the dissociation of gases of the arc into positive and negative ions, which move to opposite poles. There would be an excess of positive ions at the cathode and an excess of negative at the anode. Now if in addition we assume the positive ions to be the most rapid we would have a scarcity of them between the poles which would lower the potential of the intervening gas. There would also be a greater fall at the anode than at the cathode, which we know to be the case.

J. Paley Yorke in his book of Applied Electricity, however, says this extra fall at the anode may be due to the extra energy consumed in vaporizing the carbon. This, however, cannot be proved absolutely until a method for determining the heat of vaporization of carbon is found.

It is also known that with an alternating current the average potential of the gas is not zero. The faster movement of the positive ions will account for this because the space between the electrodes would then be charged with the more abundant negative ions which would not have time to get out of the field.

When the current is increased the resistance of the arc is apparently decreased. This is due to a more rapid process of dissociation due to the heat.

C. D. Child, the supporter of this theory, experiences some difficulty, because in other cases already examined the negative ions were the ones that outstripped their partners. When ions were drawn from a flame to charged plates and the velocity of each kind calculated it was learned that the negative were the faster. For a potential gradient of one volt per centimeter their speed was 2.6 cm. per second and that of the positive only 2 cm. per second. When a similar experiment was performed with the arc, however, the faster ions were found to be positive, no matter how the conditions were varied. The rate of discharge increased with increased current. The ratio of the speeds was 2 : 1. In the vapor of the arc, though, the negative were the faster. This may be due to a falling off in speed as the positive go farther and farther from the center.

So far only the most rapid ions of each class had been compared. But when the slower ions were considered the following results were obtained:

(1) The fastest positive ions surpassed the fastest negative ions.

(2) The slowest positive lagged behind the slowest negative ions.

The performer of these experiments then turns his attention to the discharge of hot platinum wires and of hot carbon and concludes that particles are emanated from the platinum and carbon. These particles when settling upon the negative ions retard their motion. His researches led to the belief also that the process of ionization may begin within the metal or the carbon itself. Perhaps occluded gases have something to do with it, and the arc in partial vacua also was studied. Without going into detail concerning the apparatus and its management, the results may be represented in Fig. 2

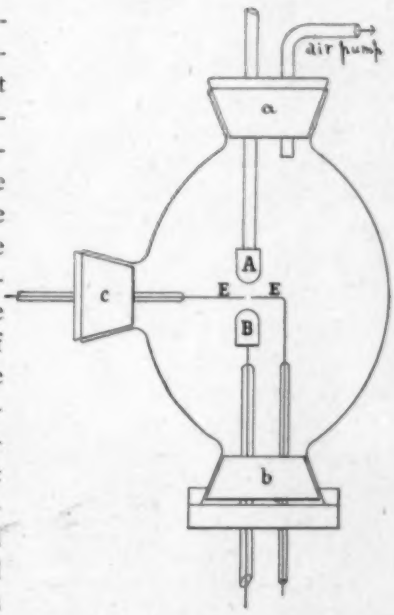


Fig. 1.

—the irregular line showing a larger drop at the anode, a uniform fall in the space between the carbons and another abrupt fall at the cathode somewhat less than that at the anode.

During these experiments an exhaust pump was connected (as shown) and pressures ranging from 730 to 2 mm. of mercury were obtained. The relative fall was always as indicated in the figure; but the drop at the negative carbon was greatest at a pressure of 100 mm. No explanation was found for this strange behavior. Thus it is seen that the conditions controlling the fall at the anode are different from those controlling that of the cathode. The electric force through the arc, moreover, was found to decrease as the pressure in the tube was lowered.

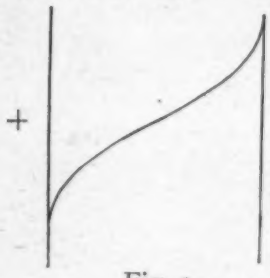


Fig. 2.

Concerning the temperature of the arc it was learned that a platinum wire .31 mm. in diameter could be melted at a pressure of 4 mm. of mercury. One .11 mm. in diameter could be melted at a pressure of 2 mm., and one that was said to be .01 mm. in diameter broke down when a pressure of .5 mm. was reached, showing that even at low pressures the temperature of the arc is very high; also proving that the value of this method of determining the exact temperature of the arc is very low.

With the same form of apparatus Child measured the rate of discharge of positive and negative ions to a surrounding cylinder and it was found that in a pressure of one atmosphere the positive ions were the faster and in very low pressures the negative ions were the more rapid.

These data present many difficulties and permit of no definite conclusions concerning what is really taking place in the arc. Yet the very fact that there are variations in the deportment of the ions under different conditions may some day lead to discoveries very valuable.

J. J. Thomson, after experiments with the discharge from platinum wires, considers ions produced within the cathode as the essential phenomenon. He says: "The essential feature in the discharge is the hot cathode, as this has to supply carriers for the electricity through the arc." Now, although a hot cathode is necessary, Weintraube has shown that in case of the mercury arc or between mercury and graphite the temperature of the mercury is far too low for the production of ions within it. It

was shown in the experiments of Child and Weintraube that no arc could be formed without a hot cathode and that there could not be two cathodes in multiple.

Now it may be that ions are formed at the boundary surface between the cathode and the surrounding gas, and that this gas boundary may be the thing that is hot, instead of the cathode itself.

It was Thomson's idea that the anode played an important role in the arc, but Weintraube proved that the part taken by it is insignificant. Thomson took it for granted also that there was no ionization going on between the carbons, but the statement is made by Child that the only way to account for the change in electrical force at the anode is to assume an increase of ions in the middle of the arc. There has been some speculation as to the cause of this extra ionization.

In atmospheric pressure the mean free path of the molecules is too small to permit of ionization by impact. In this case the high temperature must develop extra ions. In a vacuum, however, the mean free path is larger and the molecules could be broken up by impact, the temperature at the same time being lower. Again, the increase of ions at the center of the arc may be due to a change of electric force into some other form of energy.

Continuing his experiments further, Child substituted graphite terminals for the carbon. At a certain pressure, dependent upon the length of the arc used, there appeared a glow similar in appearance to the canal rays. The current seemed to emanate from the bright spot on the cathode. When a piece of platinum was introduced between the electrodes the glow always appeared, but no shadow was cast as in the case of the cathode rays. When a piece of platinum with a hole cut in it was placed close to the anode the glow seemed to pass through the opening toward the cathode, as if ions were being projected from the positive graphite terminal. The conductivity of the arc was greater when there was no glow.

When a magnet was brought near the arc at a pressure of .7 mm. or less, the gas in all parts of the tube became luminous and bright streams appeared to run from the arc to the magnet in the magnetic lines of force. Then a magnet bent into the form of a nearly completed circle was brought near and the lines then ran between the poles of the magnet. In this case the most luminous part was in the strongest magnetic field.

Thomson says: "There is a tendency for ions to follow magnetic lines of force."

Thus it is seen that the phenomena of the arc depend largely upon the electrodes used and conditions of pressure, length of arc, strength of current, and other seemingly minor details.

Besides all these, any explanation that does not consider the presence of chemical reactions would not be complete. Some years ago, and preceding the work of Child, while at Cornell University, Dr. Arthur L. Foley conducted some investigations which indicated an electrolytic action of the arc. Briefly stated these experiments were as follows: Some calcium chloride was introduced into a hollowed-out negative carbon. The anode was a plain arc carbon. The arc was allowed to operate for one minute, then the cathode was removed and after a plain carbon was substituted, the arc was again started by bringing a third carbon between the electrodes (as was done in the first case also). A photograph of the spectrum was then made which showed only those calcium lines which are in every arc due to the metal in the carbon as an impurity. The horizontal arc was used to avoid the misleading results due to convection currents. Next, the calcium chloride was inserted into the anode, the cathode being a plain carbon, and the arc was allowed to pass for one minute. On replacing the anode by a plain carbon and taking a photograph of the spectrum thus caused, numerous calcium lines were found at the cathode, due to the latter being impregnated with calcium while the salt was in the anode. The voltage was higher when the salt was in the negative pole.

The work of Dr. Foley was mainly on the "Spectra of the Arc" but these experiments show its electrolytic action.

Most of the work by Weintraube has been done in connection with mercury as a cathode and the arc in partial vacua. In many respects the conclusions reached are similar to those of other workers. He shows that besides starting the arc in the usual ways of contact and separation of electrodes and by very high voltages, it may be started also in the following ways: 1. By bringing the cathode, if mercury, in contact with an already active cathode. 2. By the cathode coming in contact with ionized vapor. 3. By mere mechanical agitation of the mercury. Like the others he shows that the cathode plays the important part in the process of ionization and that the properties of the arc are independent of the anode.

When iron, graphite or other solids are made the cathode and mercury the anode, the solid cathode always rapidly disintegrates.

This disintegration is probably intimately connected with the ionization process. "The most probable assumption," he says, "is that the current leaves the graphite in the form of carbon ions and is carried through the arc by means of mercury ions. The question whether ions after reaching the anode become positively charged and move back toward the cathode must be left undecided."

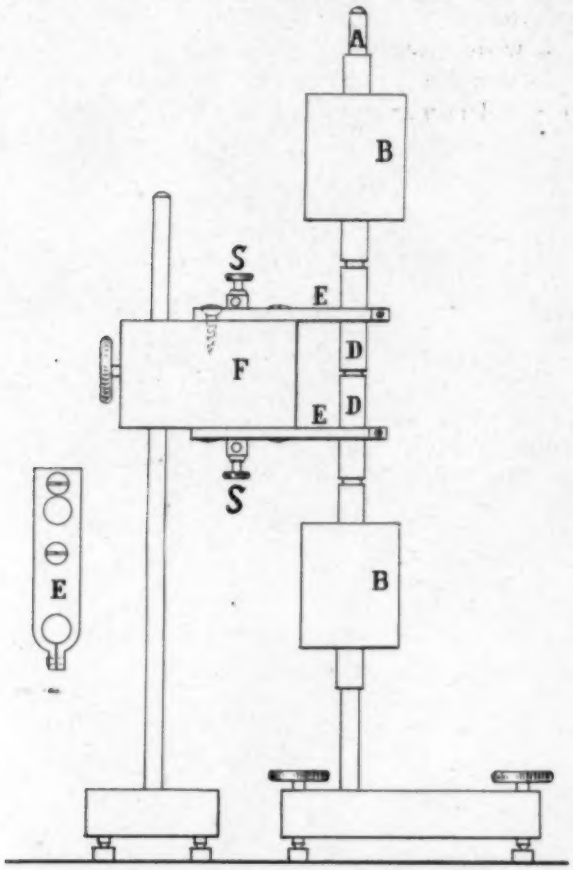


Fig. 3.

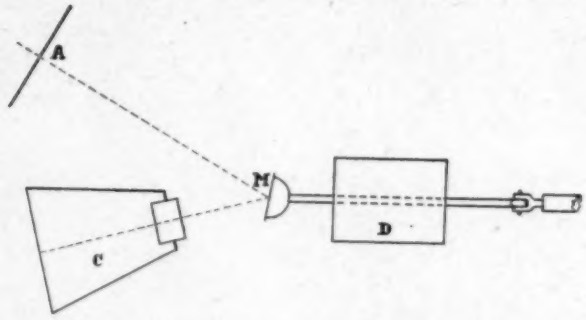
In the beginning of the year 1909 at King's College in London a series of experiments was begun by J. Nicol with the rotation of the arc in a radial magnetic field. The apparatus is illustrated in Fig. 3 and Fig. 4.

Figure 3 shows an iron rod, A, at the middle of which a magnetic pole is made by the coils B, B. F is an insulated block of wood carrying holders E, E which are supports for the copper

cylinders D D, between which the arc takes place. A top view of E is shown separately. SS are the binding screws by which the current enters and leaves DD. The apparatus is so arranged that the parts can be taken down readily for the insertion of clean copper cylinders.

The arc was started with the magnetic field already in action by inserting a carbon pencil between the copper plates D, D. Carbon terminals would permit of only a few revolutions of the arc. Iron-iron and iron mercury electrodes also were unsatisfactory. The copper cylinders were taken out and cleaned often.

To determine the number of revolutions of the arc per second a photographic method involving the use of a rotating mirror was employed. The mirror was fixed not quite normally on the end of a small motor shaft (Fig. 4). When the mirror was in



motion therefore a point source was drawn out into a circle of light and if the point source was intermittent, this circle was made up of as many dots as the number of times the source became luminous in one revolution of the mirror. The intermittent source was obtained by placing a slit in front of the arc. This was illuminated once for every rotation of the arc, and the image of the slit was photographed by an ordinary camera. The camera shutter was adjusted so that the dots overlapped a little in order that fractions of revolutions could be estimated to the nearest tenth.

Let K be the velocity of drift of an ion along the arc due to unit electric force. Then if X represent the electric force the velocity is XK. This motion of an ion in a magnetic field causes a transverse electric force of H X K to act on the ion, H being the strength of the magnetic field. This electric force gives the ion a velocity of H X K^2. Hence the transverse displacement of an ion while it is passing from one electrode to the other is this transverse velocity XHK^2, multiplied by the time to cross the

arc which is $\frac{l}{XK}$ where l is the arc length. This division gives H K l. The velocity of the two ions not being the same the arc will not remain parallel to the electrodes, but the two ends will eventually move at the same speed, and their position will be given by $y_1=vt$ for the anode end, $y_2=a+vt$ for the cathode end. The positive ion starting from the anode and moving to the cathode in a time $\frac{l}{HK_1}$ must travel a transverse distance of

$$a+\frac{vl}{XK_1} \quad \ldots\ldots\ldots\ldots(1)$$

Similarly a negative ion travels a distance transversely of

$$-a+\frac{vl}{XK_2} \quad \ldots\ldots\ldots\ldots(2)$$

Equating (1) and (2) to the expression above (H K l) we have:

$a+\frac{vl}{XK_2}=K_2 l/X$ which gives $v=HXK_1K_2$ or $K_1K_2=\frac{v}{HX}$

This may also be written $K_1K_2=\frac{2\pi rn}{HX}$ where r is the radius of the electrode and n is the number of revolutions the arc makes per second.

This product was obtained and Nicol makes the assumption that the negative ion is an electron. By calculation then the positive ion was found to be about nine hundred times the negative ion or about the mass of a hydrogen atom. "The positive ions then cannot be either copper or air molecules, but may be the same as the carriers of positive electricity detected by J. J. Thomson in the canal rays," says the author.

The product of the two velocities is directly proportional to the temperature. But the experiments show that the product is trebled by a rise in the current from two to nine amperes. This indicates a temperature change from 1,000° to 3,000° which is larger than probable. If the positive ions are copper or air molecules the rise in temperature could be accounted for by the dissociation of these groups.

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THE CATALPA TREE, AN AMERICAN PRODUCT.

By John P. Brown,
Carney, Alabama.

The aboriginal inhabitants of the region known as the Middle West, many centuries prior to the invasion by the paleface, as we learn from their legends, built their canoes of the catalpa tree, traversing long distances over prairie and through forests to obtain a wood which they could most easily work with their rude implements, and which, besides extreme lightness, as the distances of portage were frequently great, the element of durability was of vast importance to them. And furthermore as most woods when changed from conditions of moisture to those of dryness, will invariably check and split, they learned that the catalpa was free from this serious defect.

Canoes and boats made in the lower Wabash Valley were used upon the Great Lakes and far down the Mississippi.

The first historical record we have of the catalpa tree we find in early American history, when Sir Walter Raleigh in 1586 took to England three valuable American products: the potato, tobacco, and a catalpa tree. This tree was planted by Sir Francis Bacon in the garden of Gray's Inn, which at that time was a noted resort of scholars and mobility of England.

This was the well-known southern *Catalpa bignonoides*—which was indigenous to North Carolina, then a part of the Dominion of Virginia.

While Gen. William Henry Harrison was governor of the Northwest Territory he found the catalpa at Vincennes, Indiana, and learned from the Indians and early pioneers of that region the many excellent qualities of the tree, and first made known to the world its superior character.

In the city of Cincinnati, during the year 1818 General Harrison in an address to the Agricultural Society of Hamilton County, presented the claims of the Wabash Valley catalpa tree, and urged that it be planted extensively by the farmers for the production of fine hardwood lumber.

A great stimulus was given the subject by this address and also by the efforts of later advocates, so that large numbers of trees were planted; but unfortunately a vast majority were grown from southern seed and proved worthless.

The fact that we are unable to obtain enough wood of the catalpa for manufactures is because of its very high value to these pioneers, who almost exterminated the tree.

Was a gatepost wanted, because of its extreme durability the catalpa was sought. If a barn or dwelling was to be built, nothing could satisfy these pioneers for corner posts, blocks, but catalpa wood, and often these took root and grew into trees, right beside the home.

CATALPA TREE IN BLOOM, RIVERSIDE PARK, CHICAGO.

Was a plow to be repaired catalpa wood made the beam and handles. For ox bows a catalpa sapling or a pecan was bent into form and gave strength as well as bending qualities.

Shingles of the catalpa were considered the most durable and not liable to warp or split.

In fact, no matter for what purpose the wood was to be used catalpa was the first choice.

Then came the period of pioneer railway building. The Iron Mountain Road in Missouri, Illinois Central, Louisville & Nashville, Cairo Division of Big Four, Southern Railway, and many others, where they passed through the region of the catalpa forests, made first choice of this wood for cross-ties, more than a million of which were used in these earliest western roads.

These cross-ties were the most durable of any wood ever used for this purpose, thousands of them lasting over one third of a century in continual use.

The veteran car builder of Dayton, Ohio, the late Mr. Eliam E. Barney, who was an expert in knowledge of all kinds of wood placed the catalpa in the foremost ranks of valuable lumber for fine interior finish.

To Dr. John A. Warder of North Bend, Ohio, we are indebted as having discovered and made known the character of the *Catalpa speciosa,* to which he gave the name *speciosa.* All three of these early advocates of the catalpa were Ohio men, in or near Cincinnati.

About the year 1876 Mr. Robert Douglas of Waukegan, Ill., planted for Mr. H. H. Hunnewell, a director of the Kansas City, Ft. Scott & Gulf Railway, two square miles of catalpa forests at Farlington, Kansas. Thirty years afterwards this plantation becoming the property of the St. Louis & San Francisco Ry., was cleared away, the trees being sold for fence posts, brought $100,000, but there were no trees large enough for ties or lumber. The reason is obvious; 2,700 saw logs cannot be grown upon one acre of ground, and that number of trees remained without thinning four by four feet, for thirty years, the growth suppressed, merely retaining life.

Since that period many trees have been planted but the want of proper information regarding timber culture has made these experiments quite variable. Many have been planted with spurious catalpa trees, others planted too closely, still others were neglected but some have made phenomenal growth.

SEX HYGIENE AS A PART OF A COURSE IN BIOLOGY FOR BOYS AND GIRLS OF THIRTEEN TO SIXTEEN YEARS.

By Clarence W. Hahn,
High School of Commerce, New York City.

The subject of sex hygiene is one that is very much alive at pesent. Whether Mr. Hahn presents in all particulars the proper method for combating the evils arising out of sex, can probably be better determined after we have experimented more with methods of approach. In the beginning we ought to take warning from our experience in teaching the topic of alcohol and narcotics, and avoid dogmatism, which itself is an evil of the greatest magnitude. Successful experiments in teaching sex hygiene should be published for the benefit of those teachers who are still casting about in the effort to find a safe way to begin. Let us have more facts and more discussion.—Ed.

For several years a course similar to that following has been given with apparently satisfactory results, at the High School of Commerce (a school for boys), New York City. Its growth has been gradual and the sex hygiene a constant feature through a period of five years. For over a year the principle of "Prolongation of youth" or "Care and protection of young" has been employed for the purpose of emphasizing the true purpose of many sexual processes in animals, especially those that concern the human race. Lack of knowledge of these processes has been the cause of an unnatural and harmful modesty and has involved mankind in vices which threaten the demoralization of society, and finally are the means of transmitting diseases of a character detrimental to the individual, to the offspring, and to society in general.

It is intended that this course shall instruct in many other valuable phases of biology, the nature and extent of which are subject to wide variation. It is not complete in itself and should be introduced by a study of elementary science and botany and followed, at least, by some practical physiology and hygiene.

The Flower:

A knowledge of the structure of a flower is acquired through a study of some simple type or types. The function of the parts, methods of pollination and the floral devices that serve to bring them to pass, fertilization, growth in the embryo-sac, formation of the fruit and seed dispersal, are taken up as a basis for a discussion of the function of pollen and embryo-sac nuclei in carrying parental characters and this phase is illustrated with one or two concrete cases. Emphasis is laid on the facts that a species can receive new characters and thus improve through the fertilization of one nucleus by that from another plant and that the

complicated sexual structures which accomplish a cross fertilization are probably for this purpose. Emphasis is also laid on the provisions that are made by flowers for healthy hereditary characteristics, the dispersal of the seed to suitable ground for growth and the storing of food in the seed for the use of the young plant until it can manufacture its own starch and shift for itself. This is a very good place to take up the study of seeds, the kind of food stored in them, the conditions of growth, etc.

The Fish. (Some might find it profitable to introduce some invertebrates before taking up the fish.)

As a basis for human physiology, to come later, a study is made of the anatomy and physiology of the following: The skeleton (just the vertebrate plan), muscles (based on microscopic structure), blood, appendages, integument, gills and circulation, and respiratory apparatus. Then fish products, methods of catching, canning (based on earlier work in bacteria), and finally fish culture. In connection with artificial fertilization of the eggs the structure of egg and sperm are given, their growth in the ovary of the female and the spermary of the male, the process of fertilization and cleavage. In the discussion of the results of fish hatcheries, a comparison is made between the chances of survival of young fish in nature and in the hatchery and attention is called to the stored yolk and the usual lack of further protection to the growing fish.

Amphibia.

The internal structure of the frog is made the basis of human anatomy, to come later. In connection with the development of the frog, emphasis is laid on the greater protection afforded the young of amphibia by the quantity of food stored, the protecting gelatinous envelope, the deposition of sperm on the eggs at the moment of laying, and the attention to the place of laying, which is usually protected and in the vicinity of a food supply. The contrast is then pointed out between the number of young in most fishes and in most amphibia that is necessary to provide two adults to replace each pair.

Reptilia. Time permits of nothing more than a brief study of the characteristics of reptiles, their breeding habits and their economic importance. In connection with the breeding habits the following points are made: The number of young is less than in the lower classes of vertebrates: the young, being more highly developed, require a longer period of protection. To meet these two demands, nature has made their successful development more

certain in three ways; the amount of stored food in the eggs is large and additional food is secreted by the oviduct while the egg is passing from the ovary to the outside. Protection is afforded by a leathery shell so that after laying, the eggs have fewer enemies than is the case with amphibia and fishes. This necessitates *fertilization before the leathery shell is put on the egg.* Special instincts and organs are provided in the male to bring about the injection of sperm fluid (milt) into the oviduct of the female. The nesting instincts are also a step toward safety. The idea of internal fertilization as a corollary to the main principle, "the better protection of the young," is usually accepted in a philosophical way. It leads up to conditions in higher animals.

Birds. Practically nothing is done with the anatomy of this class. Much emphasis is laid upon bird protection and facts relating thereto. We also touch on the structure of the bird's egg, incubation, and the principal adaptations to flight. The idea of internal fertilization is recalled in connection with secretion of the shell and albumen by the oviduct as the egg passes to the outside. The small number of young in most species of birds is correlated with almost certain fertilization, the abundance of stored food, the security of the nests, the parental instincts, feeding and care of the young after hatching.

Mammals. The main characteristics and the economic relations of the class are the only points considered, excepting development and human physiology. The number of young in the mammals is accounted for under the following heads: Certain fertilization because of the special organs for injecting sperms into the oviduct. Better nourishment of the young because of its being attached to the oviduct and deriving food from the blood of the mother, also because of the provision of milk from mammary glands for a long time after birth; and finally the better protection of the young on account of their early development in the oviduct, the various forms of special protection afforded by the parents, by their nesting habits, their long period of mating and the leadership and defense provided by both males and females. Several good illustrations tend to add interest and at the same time divert the attention from some of the awkward questions. Special emphasis is laid upon the length of time and large amount of energy required to bring to maturity an animal of very large and complex structure. These two considerations make a reduction of the number of deaths of young an important feature.

In the case of man, the fact that the structural provisions for

the development of young are the same as in other mammals, that the high degree of development of man demands a very long period of development and a long period of childhood during which the young are protected from death or other interference with their proper development. Amongst nearly all races of men, the family exists as an institution peculiar to the human race. It provides ideal conditions for the protection of the young before and after birth. It is therefore detrimental to their proper development and against the laws of nature when the conditions of the home seriously interfere with the healthy growth and mental development of children. Immorality and disease are often responsible for such interference. Sometimes parents fail to teach their children how to properly care for themselves. Bad health, poor teeth, and immoral habits leading to degradation and death result. Masturbation in early youth may so weaken and destroy the vitality of a boy as to render him a public charge for lifetime. Home conditions may so demoralize a youth as to make him incapable of living in society with the proper moral relation to the opposite sex. In consequence of dangerous venereal diseases contracted through the improper use of the generative organs of both sexes, the protection afforded by any family may be and is continually being turned into a curse upon the children as well as the cause of disease and death of the offending parties. The effect of gonococcus bacteria upon the offspring is shown by the following figures: "From 70 to 80% of the ophthalmia which blots out the eyes of babies and 20 to 25% of all blindness is caused by this germ." Eighty per cent of all offspring infected with syphilis die before birth or soon after. The danger of youth encountering this "Great Black Plague" is due chiefly to their ignorance of its terrible consequences. The fact that 60% of the males of this country are afflicted at some time in the early part of their lives by one or the other of the above-mentioned diseases, is evidence that the sacred law of nature which works for the protection of the young of a species is transgressed, most of all, by mankind. For the highest development of youth this law must be in force in its strictest sense during a period of 18 to 20 years.

AN AMERICAN LABORATORY FOR EARTHQUAKE INVESTIGATION.

By Wm. Herbert Hobbs,
University of Michigan.

The generous support which the United States has now for many years given to its scientific bureaus under government control, has often been favorably commented upon by Europeans. In one field, however, it has fallen far behind the position taken by foreign nations. While Japan, Germany, Italy and Chile, not to mention smaller countries, have now for a number of years established strong seismological services, the Congress of the United States has not yet taken up the subject of earthquake investigation. In part this is the fault of scientific men who have either not suggested the necessity for organizing such a bureau, or have failed to urge the matter with sufficient vigor. Since the California earthquake of 1906, suitable resolutions have, indeed, been drafted and unanimously approved by the American Association for the Advancement of Science, and the Geological Society of America. These resolutions have been brought to the attention of Congress, but without visible effect. At its annual meeting in April, 1909, the American Philosophical Society passed unanimously a series of resolutions urging upon Congress the foundation of an earthquake bureau under the Smithsonian Institution for the purposes: (*a*) of collecting seismological data; (*b*) of establishing observing stations; (*c*) of organizing an expeditionary corps for the investigation of special earthquakes or volcanic eruptions in any part of the world; and (*d*) of studying and investigating special earthquake regions within the area of the national domain.

Through the active interest of Dr. W. W. Keen, the president of the American Philosophical Society, these resolutions have been brought in a favorable manner to the attention of Congress, and an amendment to the Sundry Civil Bill, now before that body, carries an appropriation of $20,000 for a "seismological laboratory" to realize the purposes of the resolutions. If favorably acted upon, this will permit of a study being made along the lines indicated. A laboratory of this nature is not independent, and hence does not require the expensive staff of clerks usually found in a separate bureau. As the work of the laboratory is expanded, its independent status can no doubt be secured.

If anyone has been under the impression that the United

States as a province are seismologically immune, and that on this account they are under no obligation to play their part in the international investigation of seismic phenomena which is now in progress, recent history should dispel the illusion. It has been officially estimated that the financial loss from the California earthquake of 1906 was $350,000,000. The estimated property loss from the shocks in South Carolina in 1886 was over $6,000,000. However, the losses from earthquakes obviously depend far less upon the intensity of the shocks than upon the possibilities of damage from them. Several earthquakes which have occurred within the national domain since the settlement of the country, have been at least equal in violence to the recent California disturbance, but, fortunately, the times and places of their visitations have been such as to render the losses almost insignificant by comparison. Thus the quake of 1663 in the St. Lawrence Valley, that of 1811 in the Lower Mississippi Valley, that of 1872 in eastern California, that of 1887 in New Mexico and Arizona, and that of 1899 in Alaska, not to mention destructive shocks of lesser violence, would some of them, if they were to be repeated to-day, result in losses to life and property which one cannot contemplate with equanimity. That the future is to bring a repetition of such violent shocks, and that many of our great cities will be the scenes of the disasters, is not questioned by any student who has investigated the subject.

Though the quakings of the earth are not under human control, there is offered to-day at least the possibility that life may in the future be safeguarded through more or less definite warnings of impending shocks; and it is already certain that the danger to both life and property can be reduced to a fraction of what it now is, through the adoption of suitable city plans, and of methods of construction based upon scientific principles.

In a broad way, many of the principles of construction suitable for application in earthquake districts have already been determined; but there is the need of extended investigation in order to fix more definitely the relative resisting qualities of different building materials, of different structural elements, and of different building types. It will be important, also, to fix the relative expense of each within each district; since earthquake construction, like fireproof construction, necessitates a large addition to the original cost. The activities of the proposed bureau of seismology would thus be naturally turned in two directions, namely: (1) scientific studies intended to increase our knowledge of the nature of earthquakes (and volcanic disturbances as well); and

(2) technical investigation intended to apply this larger knowledge to practical ends.

Each year the national domain is visited by many light earthquakes, and all data respecting especially the places where they are felt and the distribution of their intensity, should be assembled and put upon record. Reports should be issued, for in this way definite information concerning the special danger zones may be secured.

England, Germany, Japan, Italy and Chile have established organized services of widely distributed observing stations, each station reporting to a central office. In this way the occurrence of all great earthquakes in all parts of the world is immediately recorded, and soon thereafter the earthquakes may be determined in position. The lighter local shakings, also, may be located by these instruments, and their distribution of intensity more accurately fixed.

During the last few years a number of our American universities have installed seismographs suited for recording the great and so-called "distant" earthquakes, so that earthquake stations are now to be found at Cambridge, Albany, Baltimore, Washington (U. S. Weather Bureau), Ann Arbor and Lawrence. Others are to be established, or already have been, at New Haven, Reno (Nevada), and elsewhere on the Pacific Coast. The Jesuit educational institutions of the country quite independently and without advertisement of the matter, have recently developed a great system of earthquake stations. Standard Wiechert pendulums have now been installed at Worcester, Brooklyn, Fordham (N. Y.), Buffalo, Cleveland, Washington, Mobile, New Orleans, St. Louis, Chicago, Milwaukee, St. Mary's (Kan.), Denver, Spokane and Santa Clara. As yet, however, the necessary correlation of all American stations is lacking, and this could probably be carried out successfully through the medium of a central government bureau.

The studies of the past few years have shown clearly that our knowledge of quakes as regards origin and behavior, is learned less from the "distant" instrumental observations than from careful and exhaustive examinations within the disturbed district itself. Every year brings one or more grand earthquakes which occur generally in widely separated districts and often in countries where no scientific men qualified for their study are to be found.

This difficulty was early recognized by the Japanese, and their chief expert, Professor Omori, has now for a number of years

been sent out under orders from his government to study upon the ground each new quake, no matter how distant it may be. The time has, however, passed when one man without assistants or equipment can accomplish much in this direction. What is needed is a well-equipped expeditionary corps provided with a vessel adapted for the purpose, and including in its staff earthquake experts, topographers supplied with instruments for accurate mapping, photographer, and necessary assistants. By far the larger number of destructive earthquakes affect districts close to the sea, so that they may be reached by vessels, and the difficult problem of lodging and subsistence for the workers when in little civilized and unsanitary surroundings, may be best solved when a vessel is available as the base of supplies. One of the protected cruisers or gunboats now out of commission in the United States navy, could be adapted for this purpose. Judging by the record of recent years such a corps as is here suggested would be kept constantly engaged in properly reporting upon large earthquakes. There are, however, problems connected with the uplift of shore lines in earthquake provinces, which demand careful surveys, and which should throw light upon the all important question of the imminence of earthquakes in those districts.

There are a number of districts within our national domain which have been the seat of disastrous earthquakes within the last half century. The time has not passed in which valuable results may be secured through a careful study of these regions, within which the geological changes at the surface of the ground are still to be seen.

Within the last decade new building methods have evolved with a remarkable rapidity, so that those building regulations which have been adopted for well-known earthquake districts, nearly all relate to structures which have little resemblance to those of a modern occidental city. Almost the only exact studies which are available have been carried out in Japan. How best to build our cities and safeguard them from earthquake destruction, should be an important problem for the earthquake laboratory to solve.

It should be stated that members of the present Congress have shown a very commendable interest in the proposed earthquake laboratory, and the measure seems likely to be passed. Readers of SCHOOL SCIENCE AND MATHEMATICS can assure its success by drawing the attention of their representatives in Congress to the great importance of the measure.

THE HARZ.[1]

By Charles Emerson Peet,
Lewis Institute, Chicago.

The Harz Mountains are situated in Prussia about one hundred miles southwest of Berlin and about the same distance south by east of Hamburg. They occupy an area about sixty miles long in a northwest-southeast direction and about one third as wide. They are made of old slates and graywackes (with igneous intrusions), which have been turned up on edge and truncated. While the Harz are called mountains, it would be more proper to speak of the area as the dissected Harz plateau. To the north lies the North German lowland, to the southward are the Thu-

Fig. 1. A Valley in the Harz Plateau.

ringian plains. On all sides except the east the rise to the plateau surface from the surroundings is abrupt and is marked by a fault along which movement has taken place leaving the plateau high above its surroundings and making the Harz what the Germans

[1]This article was published, without illustrations, in the Educational Bimonthly. The illustrations are from "Afoot in the Harz Mountains," by W. H. Hotchkiss and C. C. Eaglesfield, Bay View Magazine, February, 1904.

call a Horst. Above the plateau surface there are conspicuous elevations like the Brocken; below it, the streams have trenched their courses in deep, narrow, and picturesque valleys like the Bodethal. To the fugitive observer some of the conspicuous elevations seen in the distance on ascending the Brocken show a significant even summit level and raise the question whether or not there are base levels represented other than that of the plateau surface. The steep slopes and much of the plateau surface are

FIG. 2. IN THE HEART OF THE HARZ.

forested and the forests are cared for in the thrifty German way. When the trees are cut from an area and the wood is harvested, it is quickly replanted with young trees. The trees may be seen in all stages of growth, from bright green patches of them that have just been planted, to areas that have a dark green color and are ready to harvest or are in the process of being cut. They do not waste much in Germany, except human labor. Near the

cities, the tree branches are stacked up in neat piles and the peasant women may be seen carrying on their backs to their homes for firewood great bundles of them that reach from high

FIG. 3. A THATCHED PEASANT HOME.

overhead to the ground on which they trail. At a distance from the villages some of the wood is made into charcoal.

The Harz region is not more thickly settled than would be expected in a much forested area. It is not attractive for agriculture but there is some good pasture ground. The region is famous for its canary birds. "In Andreasberg more than two hundred thousand are raised every year, the best singers being kept as choirmasters." Mining has been important since the tenth century in some localities, but in other localities the mines have been worked out and as is inevitable where no new industry

FIG. 4. PEASANT HOME, DANKERODE.

arises to take the place of mining, the towns have gone to decay. Silver, lead, copper, and zinc have been the chief minerals obtained from the mines. In the interior lie the mining towns of Klausthal-Zillerfeld and Andreasberg. Near the borders of the plateau the towns are situated, as along the Rhine, where the valleys open out upon the lowland. Ballenstedt, Thale, Blanken-

FIG. 5. BAD HARGBURG, THE SARATOGA OF THE REGION.

burg, Wernigerode, Bad Harzburg and the quaint old imperial city Goslar, are so situated on the north edge of the plateau.

While not on the main lines of travel for most tourists, the Harz region is made accessible to summer visitors by many lines of railroad, stage-roads, and trails, and traveling on foot through them is made easy for the stranger by the numerous guide posts which mark the way, and by the excellent maps which one may obtain for a small price. One of the favorite places visited is Thale at the point where the Bode with its entrenched meanders (map inference) emerges from the plateau onto the plains. Here one may climb by a zigzag pathway up the edge of the plateau to the "Hexentanzplatz" (Witches' Dancing Place). We climbed it at dusk. The pleasing strains of music from the German band

of a Kurhaus were wafted up to us from the village in the plain as we climbed upwards or rested on the benches stationed at places along the pathway commanding the best views. At the top of the plateau, there is a comfortable hotel to which we were guided through the darkness by a friendly German. In the stiff breezes of the night, the witches with which legend fills the region were heard holding high carnival. They were off on their broomsticks before morning for their favorite haunts on the Brocken while we waited for breakfast, which we ate out of doors at a

FIG. 6. HOUSE IN QUAINT OLD GOSLAR, AN OLD WALLED CITY, "THE LEADVILLE OF THE TENTH CENTURY."

table overlooking the deep gorge of the Bode river, before we took the more roundabout route by rail to the top of the Brocken. Before leaving we had a view looking across the plains north of the plateau. The fields of the German plains appear like a gigantic yellow and green checkerboard with elongated rectangles instead of squares. The aspect is very different from that of the great American fields. This difference has a deeper significance which cannot be discussed here.

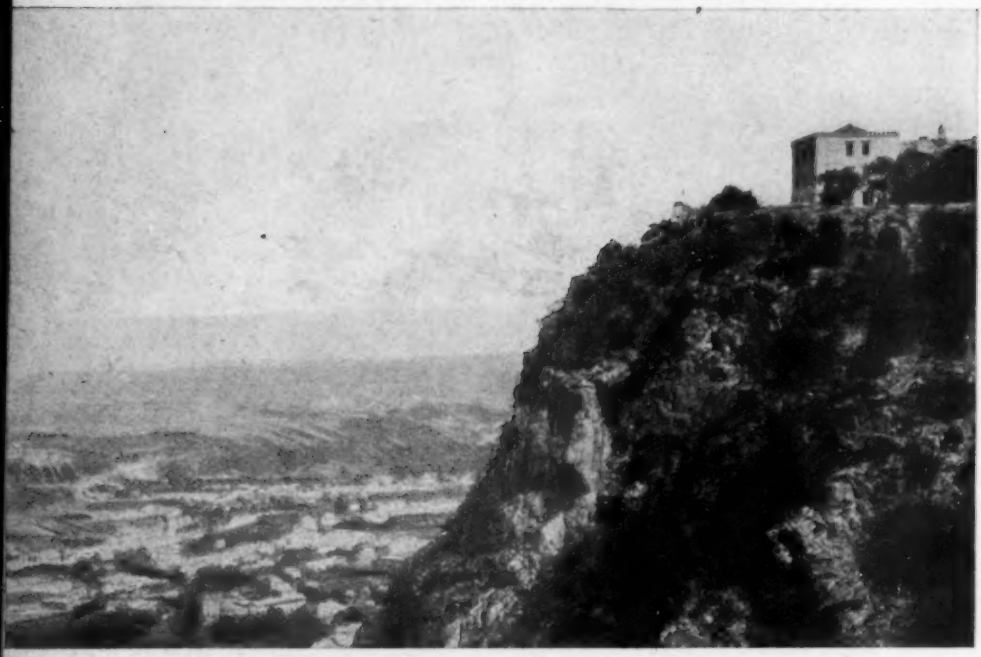


FIG. 7. THE HEXENTANTZPLANTZ HOTEL AT THE TOP OF THE PLATEAU. THALE IN THE VALLEY OF THE BODE WHERE IT OPENS ONTO THE PLAIN.

FIG. 8. THE STONE TOWER AT THE SUMMIT OF THE BROCKEN. A GROUP OF SCHOOL CHILDREN WEARING ON THEIR BACKS THE CHARACTERISTIC "SCHULMAPPE". COURTESY "AUS NAH UND FERN."

[1]Used by permission of "Aus Nah und Fern," Chicago.

The Brocken reaches an elevation of about 3,700 feet above the sea and less than half that altitude above the plateau surface. If the plateau represents a base level, this mountain is a monadnock. It is the highest mountain in north Germany and with other parts of the Harz is a favorite resort for the people of the north German cities, because of its nearness. Over thirty thousand tourists visit it every year. In clear weather its summit "commands a view with a radius of 100 miles comprising thirty cities, two or three hundred villages and one whole mountain district." But clear weather in the Brocken is rare and the writer cannot vouch for the accuracy of the statement from personal

FIG. 9. A HARZ MOUNTAIN COSTUME.

observation. The "specter of the Brocken" is also famous, but with it the traveler is rarely favored. At the top of the Brocken a moderately high stone tower affords the traveler additional facilities for a good view. As is so often the case in Germany and Switzerland, the stranger is aided in identifying the various parts

of the landscape spread out before him, by arrows cut in stone or drawn on a horizontal brass plate and properly labeled. On the north edge of the plateau within easy walking distance of the Brocken are several towns. One of these towns is Bad Harzburg, the Saratoga of the Harz, with many beautiful summer homes and numerous hotels.

From the summit of the Brocken Bad Harzburg is reached by a four hours' walk. The path is well marked so that the traveler need not go astray. One leaves the treeless summit of the

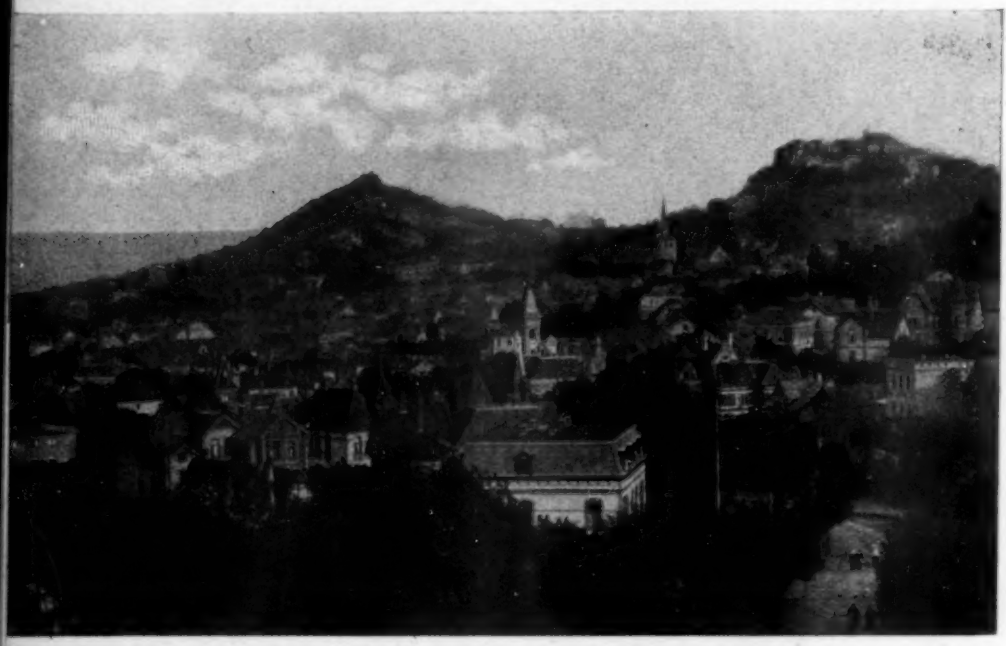


FIG. 10. BLANKENBURG. AT THE SUMMIT OF THE HILL ON THE RIGHT IS THE CASTLE—ONCE THE RESIDENCE OF THE EMPRESS MARIA THERESA, NOW THE SUMMER HOME OF THE DUKE OF BRUNSWICK.

Brocken where the railroad cuts and graded paths occasionally show a few feet of peat from which little streams of clear water flow, and soon reaches the region of small trees and thick undergrowth and then the pine forest with its impressive silence and somberness. The lofty red trunks rise from between the great moss covered blocks of rock which have given the name Blocksberg to the Brocken. Not infrequently one meets a party of

youthful Germans or a lone German youth with a long spiked staff in his hand and an alpine sack on his back, on his way to the summit. When half way down, we met one little party of three children, all under fourteen, on their way up to the summit with their father. They reached the summit, ate their lunch, enjoyed the view and returned in time to take the same train we took and yet the children were not too tired to talk freely after their shyness had disappeared. The traveler is impressed in Germany with the children. In museum, summer garden, or on a summer tramp, the children are there with their parents. Truly Germany is the land of roses and red-cheeked children!

Bad Harzburg is situated at the edge of the plateau where the valley of the Radau opens out onto the plain. Overlooking the town is the Burgberg, a hill which has been separated from the rest of the plateau by erosion. On this hilltop there is, of course, an old castle. Germany is full of them. Wherever there are butte-like outliers of a plateau in a strategic position, a castle occupies the summit. From the car window the traveler scarcely sees one disappear in the distance before another appears. On this particular hill Henry IV "built him a castle, and from this spot he started on that journey whose first stage was Canossa and whose last stage was a pauper's grave in a land of strangers." On the brow of this hill there is Bismarck Denkmal (what enterprising German town has not a Bismarck Denkmal built, building or projected?) which is inscribed with his famous saying, "To Canossa we will not go."

REFERENCES.—Grundzüge der Länderkunde by Dr. Alfred Hettner, Band I; The Bay View Magazine, February 1904; Mills' International Geography; Reclus, The Earth and Its Inhabitants.

PHYSICS CLUB OF PHILADELPHIA.

The fourth meeting of the newly formed Physics Club of Philadelphia was held at Central High School March 11, 1910, with President George A. Hoadley of Swarthmore in the chair. The secretary reported an enrolled membership of forty-three.

The program opened with a report on "The Magnetic Storm of September 25, 1909," by Dr. Paul R. Heyl of the Central High School. Dr. Heyl had had an opportunity to study this in connection with the telegraphic system of the Pennsylvania Railroad, and he made the discussion very valuable. Dr. S. T. Skidmore of Philadelphia Normal School then reported for the committee on demonstrating apparatus, and the remaining time was spent in the discussion of certain questions which had been placed in the hands of Dr. D. E. Owen of the William Penn Charter School for distribution. Among these was "What is the Nature of an Optical Image?" answered by Dr. H. C. Richards of the University of Pennsylvania. The president announced that on next Saturday morning the Club will make an excursion to the factories of the Leeds. Northrup Co. in Germantown.

GUY W. CHIPMAN, *Secretary.*

PROBLEM DEPARTMENT.

E. L. BROWN.

Principal North Side High School, Denver, Colo.

Readers of the magazine are invited to send solutions of the problems in which they are interested. Problems and solutions will be duly credited to their authors. Address all communications to E. L. Brown, 3435 Alcott St., Denver, Colo.

Algebra.

195. *Proposed by Franklin T. Jones, Cleveland, O.*

In the scale of 9 a certain number is represented by 13506. Express the same number in the scale of 4. (From a Harvard examination in Advanced Algebra.)

I. *Solution by M. T. Goodrich, Dixfield, Me., and H. M. Monroe, Veedersburg, Ind.*

13506 in scale of $9 = 1\cdot9^4+3\cdot9^3+5\cdot9^2+0\cdot9+6 = 9159$ in scale of 10.

Let $a\cdot4^n + b\cdot4^{n-1} + \ldots\ldots + m\cdot4 + n = 9159$.

The digits $a, b \ldots\ldots m, n$ will be the remainders obtained by successive division by 4.

4	9159	
4	2289	$+ 3 = n$
4	572	$+ 1 = m$
4	143	$+ 0 = \&c$
4	35	$+ 3$
4	8	$+ 3$
	2	$+ 0$ $\therefore$ the number is 2033013

II. *Solution by G. B. M. Zerr, Philadelphia, Pa.*

4	13506	
4	3123	$+ 3$
4	705	$+ 1$
4	168	$+ 0$
4	38	$+ 3$
4	8	$+ 3$
	2	$+ 0$ Hence 13506 in scale of 9 = 2033013 in scale of 4.

Explanation: Since 4 will not divide 1, multiply 1 by the radix of the scale, 9, add to next integer, and divide by 4; $1\times9=9$, $9+3=12$, $12\div4=3$. Next, $5\div4=1$ with a remainder of 1. Multiply this remainder by the radix, add to next integer, and divide by 4: $1\times9=9$, $9+0=9$, $9\div4=2$ with a remainder of 1. Similarly, $1\times9=9$, $9+6=15$, $15\div4=3$ with a remainder of 3. This remainder is the first of units' digit of the number expressed in the scale of 4. Continue in this way until the quotient is less than 4.

196. *Proposed by H. L. McAlister, Arkadelphia, Ark.*

In how many ways can 7 pears, 5 apples, and 4 oranges be given to 16 children, each child to receive a piece of fruit?

Solution by Walter L. Brown, Albion, N. Y.

The seven who receive pears may be chosen in $\frac{16!}{7!\ 9!}$ ways.

The five who receive apples may be chosen from the remaining nine in $\frac{9!}{5!\,4!}$ ways.

The four who receive oranges may be chosen from the remaining four in 1 way.

∴ The number of ways of distributing the fruit is

$$\frac{16!}{7!\,9!} \times \frac{9!}{5!\,4!} \times 1 = 1{,}441{,}440.$$

197. *Proposed by H. E. Trefethen, Kent's Hill, Me.*

Two men travel by day in the same direction round and round an island, 20 miles in circumference, and camp at night. A has two miles the start, and goes three miles a day uniformly. B goes one mile the first day, two the second and so on, increasing his rate one mile each day. When do they first camp together?

Solution by John A. Hardin, Ft. Bliss, Texas.

In order to make the solution general, we may take into account the traveling of A and B prior to this particular time at which they camped with A two miles in the lead. The daily distances covered by B will then be represented by the series, ...—4, —3, —2, —1, 0, +1, +2, +3, +.... that is, prior to this particular time B traveled in the opposite direction to that of A, the distances covered each day being the absolute values of the negative terms of the series, and after this time he traveled in the same direction as A, as indicated by the positive terms of the series.

Now let $x =$ in absolute value the number of days traveled before they *will* camp together or since they *did* camp together.

$3x+2 =$ then in absolute value the distance of A from the point where B reversed his direction of traveling, and

$\frac{x}{2}(x+1) =$ in absolute value the distance of B from the same point

(barring in each case probably a multiple of 20 miles).

∴ by the conditions of the problem

$$\frac{x}{2}(x+1)-(3x+2)=20k \text{ (where } k \text{ is an integer).}$$

$$\therefore\ x = \frac{5 \pm \sqrt{160k+41}}{2} \quad \ldots\ldots\ldots\ldots (1)$$

Since x can have rational values only,

$160k+41=i^2$ (where i is an integer).

$160k=i^2-41$.

Since k is an integer (now obviously a positive integer different from 0), it is evident that i must be an integer having for its units' digit 1 or 9. This is a necessary but not a sufficient condition in order that i^2-41 may be divisible by 160. It is clear also that if i is such an integer that i^2-41 is divisible by 160, then $(80m \pm i)^2-41$ is also divisible by 160 (m being any integer, positive or negative). Moreover the opposite statement holds, viz: if i is such an integer that i^2-41 is not divisible by 160, then $(80m \pm i)^2-41$ is also not divisible by 160. As negative integral values of m are to be admitted, the lower sign of i in $(80m \pm i)^2-41$ may be omitted. Let it be noted now that *every* integer whose units' digit is 1 or 9 may be expressed in the form, $80m \pm i$, where i is restricted to the values 1, 11, 21, 31, 41, 51, 61, 71 (m being an integer positive or negative). Therefore in the present argument, the equation $160k=i^2-41$, in which it would be necessary to consider substitutions for i of numbers in general whose units' digits are 1 or 9, may be replaced by the equation $160k=(80m+i)^2-41$,

in which it is necessary to consider only the following substitutions for i: 1, 11, 21.....71.

By trial it is found that if i=51 or 61, i^2—41, and consequently $(80m+i)^2$—41 is divisible by 160; and that if i=1, 11, 21, 31, 41, or 71, i^2—41 and consequently $(80m+i)^2$—41 is not divisible by 160. Therefore the equations

$160k=(80m+51)^2-41$.....(2)

and $160k=(80m+61)^2-41$.....(3)

in which the substitution for m of any integer, positive or negative, or 0, is allowed, will furnish *all* the solutions for k that are admissible.

Now consider

$$x=\frac{5\pm\sqrt{160k+41}}{2}\quad\ldots\ldots\ldots\ldots(1)$$

together with

$160k=(80m+51)^2-41$.....(2)

and $160k=(80m+61)^2-41$.....(3)

Eliminating k from (1) and (2) and from (1) and (3) we obtain respectively:

$x=40m+28$ or $-(40m+23)$

and $x=40m+33$ or $-(40m+28)$.

The following solutions are obtained by some substitutions for m:

$m=0$; $x=28, -23, 33, -28$.

$m=-1$; $x=-12, 17, -7, 12$.

$m=1$; $x=68, -63, 73, -68$.

etc.

This process may, of course, be continued indefinitely. The least positive value of x, x=12, answers the question asked in the problem as stated.

Geometry.

198. *Selected.*

Let ABCD be a cyclic quadrilateral, having AB=a, BC=b, CD=c, DA=d, AC=p, BD=q.

Prove: (1) $\frac{p}{q}=\frac{ad+bc}{ab+cd}$;

(2) $p^2=\frac{(ac+bd)(ad+bc)}{ab+cd}$, and $q^2=\frac{(ac+bd)(ab+cd)}{ad+bc}$.

I. *Solution by G. B. M. Zerr, Philadelphia, Pa.*

Let B be an acute angle. Let BE be the projection of BC on AB, DF the projection of AD on CD.

Then $p^2=a^2+b^2-2a\cdot BE=c^2+d^2+2c\cdot DF$.

Since angle B=angle ADF, the right triangles ADF and BCD are similar.

$\therefore BE:DF=b:d$, or $DF=\frac{d\cdot BE}{b}$.

$\therefore a^2+b^2-2a\cdot BE=c^2+d^2+\frac{2cd}{b}\cdot BE$.

$\therefore BE=\frac{b(a^2+b^2-c^2-d^2)}{2(ab+cd)}$.

$\therefore p^2=a^2+b^2-\frac{ab(a^2+b^2-c^2-d^2)}{ab+cd}=\frac{(ac+bd)(ad+bc)}{ab+cd}$.

Similarly, $q^2=\frac{(ac+bd)(ab+cd)}{ad+bc}$

By division, $\frac{p^2}{q^2}=\frac{(ad+bc)^2}{(ab+cd)^2}\quad\therefore\frac{p}{q}=\frac{ad+bc}{ab+cd}$.

II. *Solution by H. E. Trefethen, Kent's Hill, Me.*

Let F be the intersection of the diagonals. Then by similar triangles

AF/BF=d/b, BF/FC=a/c, whence by multiplying AF/FC=ad/bc. By composition the latter gives $p/AF=(ad+bc)/ad$ and similarly $q/BF=(ab+cd)/ab$, whence $p/q=(ad+bc)/(ab+cd)$.

Take point E in BD so that angle DAE = angle BAC. Then by similar triangles AC·BE=AB·DC and AC·DE=AD·BC, whence by adding $pq=ac+bd$. Combining this with $p/q=(ad+bc)/(ab+cd)$ we get $p^2=(ac+bd)(ad+bc)/(ab+cd)$, $q^2=(ac+bd)(ab+cd)/(ad+bc)$.

III. *Solution by Editor.*

Let r= radius of circumscribed circle. Then

$$ABCD = ABC + ADC = \frac{abp}{4r} + \frac{cdp}{4r} \quad \ldots\ldots\ldots\ldots (1)$$

$$\text{Also } ABCD = ABD + CBD = \frac{adq}{4r} + \frac{cbq}{4r} \quad \ldots\ldots\ldots (2)$$

From (1) and (2) $\frac{p}{q} = \frac{ad+bc}{ab+cd}$ (3). By Ptolomy's Theorem $pq=ac+bd$ (4)

From (3) and (4) we find values for p^2 and q^2.

199. *Proposed by I. L. Winckler, Cleveland, O.*

If ABCD is a cyclic quadrilateral, prove that the centers of the circles inscribed in triangles ABC, BCD, CDA, DAB are the vertices of a rectangle.

More solutions desired.—Ed.

Trigonometry.

200. *Selected.*

From $a/\sin A=b/\sin B=c/\sin C$, derive $a^2=b^2+c^2-2bc\cos A$.

I. *Solution by H. E. Trefethen, Kent's Hill, Me., and M. H. Pearson, Montgomery, Ala.*

$a/\sin A=b/\sin B=c/\sin C$. Also $\sin A=\sin(B+C)=\sin B\cos C+\cos B\sin C$. Whence $a=b\cos C+c\cos B$, and similarly $b=c\cos A+a\cos C$, $c=a\cos B+b\cos A$. Multiply these in order by $-a$, b, c and add, then $a^2=b^2+c^2-2bc\cos A$.

II. *Solution by O. R. Sheldon, Chicago, Ill.*

$\sin C=\sin(A+B)$.

$$\therefore \frac{c \sin A}{a} = \sin A \cos B + \cos A \sin B \quad \ldots\ldots\ldots\ldots (1)$$

$$\text{But } \sin B = \frac{b \sin A}{a}. \quad \text{Therefore from (1)}$$

$$c = a \cos B + b \cos A.$$

$$\text{Hence } (c - b\cos A)^2 = a^2 \cos^2 B = a^2\left(1 - \frac{b^2 \sin^2 A}{a^2}\right),$$

or $c^2-2bc\cos A+b^2\cos^2 A=a^2-b^2\sin^2 A$.

$\therefore a^2=b^2+c^2-2bc\cos A$.

III. *Solution by E. Kesner, Salida, Colo., and I. L. Winckler, Cleveland, O.*

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{\quad}{\sin C}.$$

$$\therefore \frac{a^2}{\sin^2 A} = \frac{b^2}{\sin^2 B} = \frac{c^2}{\sin^2 C} = \frac{2bc \cos A}{2 \sin B \sin C \cos A}$$

$$\therefore \frac{a^2}{\sin^2 A} = \frac{b^2 + c^2 - 2bc \cos A}{\sin^2 B + \sin^2 C - 2 \sin B \sin C \cos A}.$$

Now

$\sin^2 B+\sin^2 C-2\sin B\sin C\cos A$

$=\sin^2 B+\sin^2 C+2\sin B\sin C\cos(B+C)$

$=(\sin B\cos C+\cos B\sin C)^2$

$=\sin^2(B+C)=\sin^2 A$

$\therefore a^2=b^2+c^2-2bc\cos A$.

CREDIT FOR SOLUTIONS RECEIVED.

Algebra 190. M. T. Goodrich (1).

Algebra 191. M. T. Goodrich, H. G. McCann (2).

Geometry 192. M. T. Goodrich, H. G. McCann (2).

Algebra 195. Wm. B. Borgers, W. L. Brown, M. T. Goodrich, John A. Hardin, E. Kesner, H. L. McAlister, H. G. McCann, O. M. Miller, H. M. Monroe, M. H. Pearson, Orville Price, J. L. Riley, H. E. Trefethen, I. L. Winckler, G. B. M. Zerr (15).

Algebra 196. Wm. B. Borgers, W. L. Brown, A. M. Harding, M. H. Pearson, H. G. McCann, H. M. Monroe, Orville Price, H. E. Trefethen, I. L. Winckler, G. B. M. Zerr (10).

Algebra 197. Wm. B. Borgers, W. T. Brewer, W. L. Brown, M. T. Goodrich, E. G. Hapgood, John A. Hardin, A. M. Harding, E. Kesner, M. H. Pearson, Orville Price, Gertrude L. Roper, H. E. Trefethen, I. L. Winckler, G. B. M. Zerr (14).

Geometry 198. A. M. Harding, E. Kesner, M. H. Pearson, Orville Price, H. E. Trefethen, I. L. Winckler, G. B. M. Zerr (7).

Geometry 199. I. L. Winckler (1).

Trigonometry 200. W. L. Brown, M. T. Goodrich, John A. Hardin, A. M. Harding, E. Kesner, M. H. Pearson, Orville Price, J. L. Riley, O. R. Sheldon, H. E. Trefethen (two solutions), I. L. Winckler, G. B. M. Zerr (13).

Total number of solutions, 65.

PROBLEMS FOR SOLUTION.

Algebra.

207. *Proposed by Franklin T. Jones, Cleveland, Ohio.*

Extract the cube root of $2\pm11\sqrt{-1}$.

208. *Proposed by H. E. Trefethen, Kent's Hill, Me.*

The quantity of coal consumed by a steamer varies as the cube of her speed, being 1.5 tons an hour when the speed is 15 miles an hour. If coal costs \$4.50 per ton and the other expenses are \$4.00 an hour, find the least cost for a voyage of 2,000 miles.

Geometry.

209. *Selected.*

A, B, C are three fixed points. Describe a square with one vertex at A, so that the sides opposite to A pass through B and C.

210. *Proposed by W. W. Beman, Ann Arbor, Mich.*

Give a *direct* demonstration of the theorem, If the sum of two opposite sides of a quadrilateral is equal to the sum of the other two sides, the quadrilateral may be circumscribed about a circle.

211. *Proposed by W. W. Beman, Ann Arbor, Mich.*

Give a *direct* demonstration of the theorem, If the sum of two opposite angles of a quadrilateral is equal to the sum of the other two angles, the quadrilateral may be inscribed in a circle.

NOTE.—The demonstrations of Theorems 210 and 211 must not depend on theorems which themselves have been established by indirect methods.

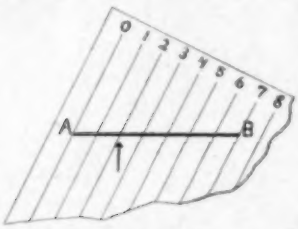
REAL APPLIED PROBLEMS IN ALGEBRA AND GEOMETRY.

COMMITTEE ON INVESTIGATION: JAMES F. MILLIS, *Chairman, Francis W. Parker School, Chicago;* JOS. V. COLLINS, *State Normal School, Stevens Point, Wis.;* C. I. PALMER, *Armour Institute of Technology, Chicago;* E. FISKE ALLEN, *Teachers College, New York, N. Y.;* A. A. DODD, *Manual Training High School, Kansas City, Mo.*

Teachers are invited to contribute problems to these columns, and to try out in the class room the problems that are here printed.

For the convenience of teachers who wish to use them, the problems printed in SCHOOL SCIENCE AND MATHEMATICS up to November, 1909, have been rearranged and grouped according to the parts of the subjects of which they are applications. They are bound in pamphlet form, so that a copy may be placed in the hands of each pupil. These pamphlets may be secured in any quantity, at 5c a copy, from the Secretary of the Mathematics Section, Miss Mabel Sykes, Bowen High School, Chicago, Ill.

By W. E. Stark, Ethical Culture School, New York.

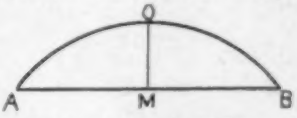


1. The following device is sometimes used for determining the position of contour lines, in making a topographical map.

It is required to divide the line AB into segments having the ratio of 2 to 5. A piece of tracing cloth is used having a series of equidistant parallel lines ruled upon it. With line O passing through A, the piece of cloth is rotated until line 7 passes through B. The required division is made by pricking through the cloth with a needle at the intersection of line 2 with AB. Prove it.

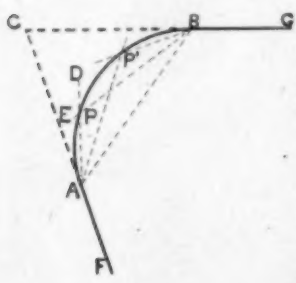
By Arthur W. Belcher, Teachers College, New York.

2. A simple way for finding the radius and center of any given circular curve, such as a street railway track, is as follows:



Stretch a steel tape between any two points A and B of the curve, and measure MO (called the "middle ordinate"), which is the shortest distance from the midpoint of AB to the curve. Proceed by finding a third proportional to OM and MB. Show that this will give how thus to get the radius. Show how the center may then be located.

3. In surveying, to find points on a curve which will join FA to BG, the points of tangency A and B must be taken so that CA=CB. Divide angle CAB into any number of equal parts. With a transit (instrument for laying off angles in the field, etc.) at A, sight a direction AD so as to make angle DAC equal to one of the equal parts. With another transit at B, sight along BE, having made the angle ABE equal to angle DAC. The intersection P of the two directions AD and BE will be a point on the curve (circle). Why?



By turning off successively additional angles equal to angle DAC from A and B, respectively, other points such as P' on the curve may be located, until finally the transit at A points along the direction AB, while that at B points along the direction BC.

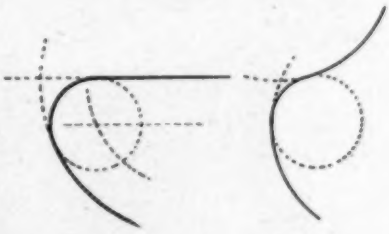
4. When on a train one may approximate its speed by counting the

"clicks" that are made by the car wheels as they pass over the joints between rails. The number of rails passed over in 20 seconds usually is approximately equal to the speed in miles per hour. (a) Find the length of rail in use. (b) For how many seconds should one count if the rails are 45 ft. long?

5. Where two straight streets intersect, each corner is usually "rounded off." Show that the problem of laying out the corner arc is a simple one where the streets made an angle of 90°. Show by a plan how to lay out a corner where the angle is 45° and the radius for the curved curbing is to be 20 ft. Find the total length of curved curbing needed.

6. A straight street intersects one which is curving (with a large radius, such as 200 ft.), and the corner is to have a small radius, say 15 ft. Show in a plan how to find the center for the corner arc by means of the intersection of two loci.

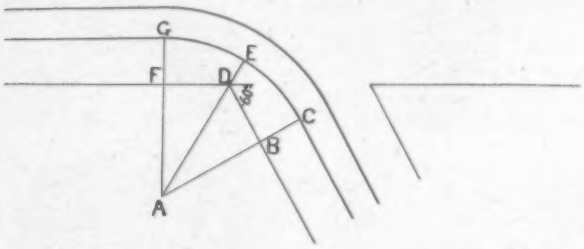
How would you get, in actual field work, the curving locus? (Note its large radius.)



7. Solve in another plan the corresponding problem where both streets are curved.

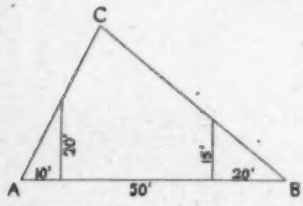
By John H. Bortz, High School, Greensburg, Pa.

8. A street car track is 12′ from the curb (GF=BC=12′). In passing the corner of two streets which deflect through an angle of 60° the rail must be 5′ (DE=5′) from the corner. (a) Find radius of curve. (b) Find



length of tangents from G and C. (c) Find length of arc GC; also length of outer arc. Width of track is 4′ 8½″.

9. If two streets deflect through an angle of 90°, answer the same questions as in the preceding problem, using the same data.



10. The distance between two points A and B is 50′. At B construct a line such that the rise will be 15′ in every 20′ measured on AB from B. At A construct a line such that the rise will be 20′ in every 10′ measured on AB from A.

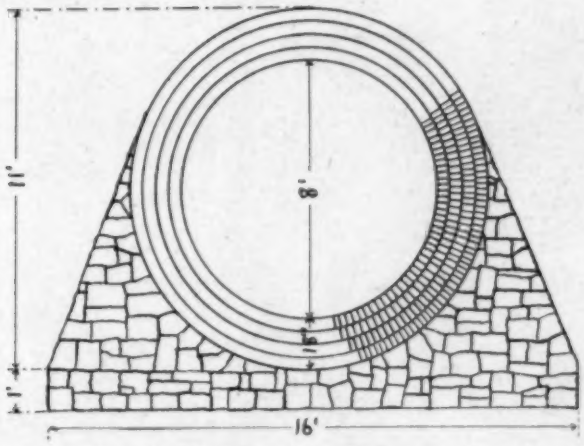
(a) Make the construction.

(b) Compute the distances AC and BC.

SUGGESTION: Draw altitude from C and use similar triangles to find the altitude.

11. The figure represents a cross section of a circular brick culvert, of

four rings of brick. Compute the volume of each ring, supposing the culvert to be 50′ long.



Make an estimate of the stone work shown in the figure; that is, compute the volume of the stone work.

ADDITIVE SUBTRACTION.[1]

MR. W. LAWRENCE MURPHY,

Prescott Grammar School, Boston.

Of the various so-called fundamentals in arithmetic there is no one which is a greater misfit for the affairs of everyday life than subtraction as presented in most of the text-books, and taught in the average school room in this country at the present time.

Here is a typical democratic problem which will clearly illustrate this fact: In a fifty-seven cent purchase a dollar bill has been tendered in payment. The text-book or school book says, "fifty-seven cents from one dollar leaves forty-three cents," to be returned in any form imaginable. The clerk, the cashier, the merchant, or the banker says, "fifty-seven cents and three and five and ten and twenty-five makes one dollar," picking out the change as he counts. Hence the change or complementing method of subtraction must be learned sometime by people connected with trade, commerce, or finance, if they are expected to compute or make change rapidly and accurately.

Generally speaking, I am somewhat inclined to be conservative with regard to new and doubtful methods. Unless I can see some very decided advantage to be gained by their adoption, I consider it unwise to upset time-honored customs simply for the sake of experiment. With regard to this particular topic, however, I believe it can be clearly shown that we teachers here in the United States have been clinging to an antiquated process, which all other progressive countries have discarded, and which we ourselves habitually discard as soon as we are called upon to adapt our school work to practical business transactions.

[1]Read before the Association of Mathematical Teachers in New England, March 27, 1909.

Before entering upon a brief analysis of this method I wish to quote briefly a few words from prominent authorities with regard to it.

David Eugene Smith, Professor of Mathematics, Teachers' College, Columbia University, in his "Teaching of Elementary Mathematics," page 121: "In subtracting 297 from 546 we have two old plans, both dating from the time of the earliest printed books:

"(1) 7 from 16, 9; 9 from 13, 4; 2 from 4, 2.

"(2) 7 from 16, 9; 10 from 14, 4; 3 from 5, 2.

"But we have also a more recent plan:

"(3) 7 and 9, 16; 10 and 4, 14; 3 and 2, 5.

"All of these plans are easily explained, the first rather more easily than the others. But the third has the great advantage of using only the addition tables in both addition and subtraction, and of saving much time in the operation. It is the so-called Austrian method of subtraction. The old expressions, borrow and carry, have no advocates of any prominence to-day."

Mr. John H. Moore, author of "Moore's Commercial Arithmetic," and joint author of "Moore and Miner's Book-keeping": "*This* method is easily explained and when once learned is more rapid than the old method. It is used by all competent cashiers and accountants. It reduces the work in many business exercises fully fifty per cent."

Preliminary Report of the Arithmetic Committee of this Association: "It is at the present time quite generally believed by the best authorities on Arithmetic that a great saving of time could be effected by adopting the 'shop' or 'complementary' method of subtraction. By using this method the subject could be taught at the same time, and by means of the same kind of presentation as addition. The terms minuend, subtrahend, and remainder, as well as the numerous subtraction tables and combinations are unnecessary in teaching subtraction by this method, as the difference or complement is the result sought, and this idea is inherent in the simplest addition processes."

Edward M. Langley, Editor *Mathematical Gazette*, London: "The ordinary 'school' method of subtraction should be at once discarded in favor of the 'shop' or 'complementary' method; the problem in subtraction being looked upon as an inverse question in addition. The chief object in getting thoroughly used to the above method of doing subtraction is to be able to extend it subsequently to long division."

After several years of practical experience with this method in my own classes and with three different corps of teachers, I am convinced that its advocates do but weakly emphasize its advantages. Most of them (especially those on this side of the Atlantic), while applying the addition process to simple integral expressions, fail to follow it out to its logical conclusion: viz., in the subtraction of mixed numbers, compound numbers, and in the extraction of square root. I am convinced that the complete and universal adoption of this method of subtraction would save fully one-third of the time given at present to arithmetic, besides obviating the necessity of learning a new method for use in after life.

The greater safety to life and property of steel constructed cars over the wooden type has again been demonstrated in the recent collision between two trains in the Hudson River tunnel. No injury was sustained by the passengers except a general shaking up, which is inevitable when heavy masses like these cars come together.

SOME TEACHERS' QUERIES.[1]

Under the title of "The Question Box," several questions were considered by a committee appointed for the purpose; and the Association asked that the secretary should include them in his report of the meeting of December 5, 1908.

The suggestion was made two or three times that the Association should devote more attention than it had hitherto to the connection between elementary school work and secondary school work, instead of practically confining its attention to the connection between high school and college.

Some of the questions were as follows:

"Is it to be expected that a teacher would answer offhand the following question: If all the linear dimensions of a plane figure be increased by one-ninth, by how much is the whole area increased?"

"How do you interpret the question point in a locus? For example, locus of the vertices of isosceles triangles having the same base. Is it the perpendicular bisector except the points of intersection, or the perpendicular bisector with no exception?"

"What is the relative value of long and short assigned lessons in mathematics?"

"What is the shortest method of finding the area of a pentagon, one side of which is 8 feet?"

(The method suggested was to use the trigonometrical formula

$$S = \frac{5c^2}{4} \tan . 54^\circ$$

"To draw an equilateral triangle having its vertices in three parallel lines."

(The method suggested at the meeting was to divide the base in the ratios of the distances of the parallel lines; to draw a line from the point of section to the vertex; then parallels to that line through the extremities of the base. A similar figure can then be constructed on the three given parallel lines.)

An interesting discussion arose upon the question of significant figures. The question stated two definitions:

(1) That the first significant figure is the first figure on the left which is not a cipher. All others to the right are significant.

(2) That significant figures are those that remain after the ciphers at the right or the left are canceled.

Instances were given of numbers containing zeros that were significant; for example, the number 39.370, which is by legal definition the number of inches in a metre; and of numbers containing zeros that were not significant; for example, 92,000,000, the radius of the earth's orbit, which could otherwise be written 92×10^6.

The discussion brought out substantially the following definition:

The figures 1, 2, 3, 4, 5, 6, 7, 8, 9, are always significant; 0 is significant when it comes between digits known to be significant; never when it is not preceded by one of the other nine digits; and never when it is used merely to fix the position of the decimal point. The 0 that sometimes occurs as the last digit in a decimal fraction is just as significant as a 1, 2, 3. . . in the same place; otherwise it has no reason at all for being written.

The weight of opinion was decidedly that where it was necessary to fix the decimal point by the use of ciphers, the only way to decide what numbers are significant is to put down the significant part of the number, and

[1] Read at the meeting of the Association of Mathematical Teachers in New England December 5, 1908.

then multiply it by a power of 10, as in the case of the radius of the earth's orbit, given above.

Mr. Tower submitted a question as follows: Why not discard in elementary schools the historic method of finding the square root in favor of this: Divide the given number by trial root. Split the difference between divisor and quotient, and try again, continuing until the desired accuracy is obtained.

The general opinion in regard to this suggestion was quite favorable, though the Association took no formal action.

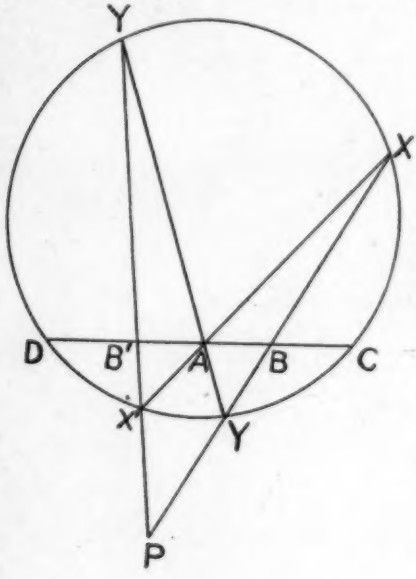
Professor Bouton suggested the problem which follows:

In any circle, let M be the middle point of any chord a. Let two chords be drawn through the point M, intersecting the circle above and below the chord. Let the right-hand ends of these chords be joined by a line which intersects a at X, and the left-hand ends by a line which intersects a at Y. To prove that MX=XY.

There appeared to be a general disposition to postpone action on this question.

April 1, 1909, the secretary received from Dr. Julian L. Coolidge the following solution:

A is the middle point of the chord DC; XY is an arbitrary chord through B (arbitrary on AC).



To prove AB=AB'.

$\overline{BX}\cdot\overline{BY}=\overline{BC}\cdot\overline{BD}=\overline{AC}^2-\overline{AB}^2$.

$\overline{B'X'}:\overline{B'Y'}=\overline{B'C}:\overline{B'D}=\overline{AC}^2-\overline{AB'}^2$.

(AD=AC).

Consider the triangle PBB' and transversal XX'.

Then by Menelaus' theorem,

$\overline{BX}\cdot\overline{AB'}\cdot\overline{PX'}=\overline{PX}\cdot\overline{AB}\cdot\overline{B'X'}$.

Similarly, $\overline{BY}\cdot\overline{AB'}\cdot\overline{PY'}=\overline{PY}\cdot\overline{AB}\cdot\overline{B'Y'}$.

Multiplying and remembering $\overline{PX}\cdot\overline{PY}=\overline{PX'}\cdot\overline{PY'}$.

$\overline{AB'}^2\cdot\overline{BX}\cdot\overline{BY}=\overline{AB}^2\cdot\overline{BX'}\cdot\overline{BY'}$.

Hence $\dfrac{\overline{AB'}^2}{\overline{AC}^2-\overline{AB'}^2}=\dfrac{\overline{AB}^2}{\overline{AC}^2-\overline{AB}^2}$.

That is, $(AB')^2=(AB)^2$.

SCIENCE QUESTIONS.

Questions and Problems for Solution.

25. *Proposed by Chas. H. Korns, Bradford, Pa.*

An oil derrick 80 ft. high is 6 inches out of plumb at the top. How many inches must the base on that side be raised to true the top, if the base is 20 ft. square?

26. *Proposed by a student in the class of H. A. Hill, Delafield, Wis.*

How may the total pressure on an electric light bulb be calculated?

The question was referred to the class by Mr. Hill. One solution, which was not accepted, was as follows: Find the volume of the bulb by displacement in water. Measure the longest transverse diameter of the bulb. Assuming that volume and measured diameter to be the volume and diameter respectively of a cylinder, calculate the altitude of the cylinder. With the measured diameter and calculated altitude find the area of the cylinder which was assumed to be equal to the area of the bulb.

Where is the fallacy? What is the correct solution?

19. *Proposed by G. B. M. Zerr, Philadelphia, Pa.*

An equilateral triangle has its altitude vertical and its vertex in the surface of water. Five sixths of its altitude is in water and one sixth in a denser liquid. Find the density of this latter liquid if the pressure on the areas immersed in each liquid is equal.

Solution by the proposer—

Let a equal side given triangle.

Then $\frac{1}{2}a\sqrt{3}$=altitude.

$\frac{5}{6}$ of $\frac{1}{2}\ a\sqrt{3} = \frac{5}{12}\ a\sqrt{3}$ = altitude of portion in water.

$\frac{1}{6}$ of $\frac{1}{2}\ a\sqrt{3} = \frac{1}{12}\ a\sqrt{3}$ = altitude of trapezoid in denser liquid.

$\frac{5}{6}a$=base of triangle in water and the upper base of trapezoid in denser liquid.

Hence $\frac{1}{2}$ of $\frac{5}{6}a \times \frac{5}{12}a\sqrt{3} = \frac{25a^2\sqrt{3}}{144}$ = area in water.

$\frac{1}{4}\ a^2\sqrt{3} - \frac{25\,a^2\sqrt{3}}{144} = \frac{11a^2\sqrt{3}}{144}$ = area in denser liquid.

The distance of the center of gravity of the area in water from the vertex $= \frac{2}{3}$ of $\frac{5}{12}\,a\sqrt{3} = \frac{5}{18}a\sqrt{3}$.

Let x = distance of center of gravity of trapezoid from vertex of triangle.

Then $x \times \frac{11a^2\sqrt{3}}{144} = \frac{1}{3}a\sqrt{3} \times \frac{1}{4}a^2\sqrt{3} - \frac{5}{18}a\sqrt{3} \times \frac{25a^2\sqrt{3}}{144}$

$$\therefore x = \frac{91a\sqrt{3}}{198}$$

$\frac{91a\sqrt{3}}{198} - \frac{5}{12}a\sqrt{3} = \frac{17a\sqrt{3}}{396}$ = distance of center of gravity of trapezoid from upper base.

Let d = density of lower liquid.

Then $\frac{25a^2\sqrt{3}}{144} \times \frac{5}{18}a\sqrt{3} = \left(\frac{17a\sqrt{3}}{396}\rho + \frac{5}{12}a\sqrt{3}\right)\frac{11a^2\sqrt{3}}{144}$

$$\therefore \frac{125}{198} - \frac{5}{12} = \frac{17}{396}d$$

$$\therefore \frac{85}{396} = \frac{17}{396}d$$

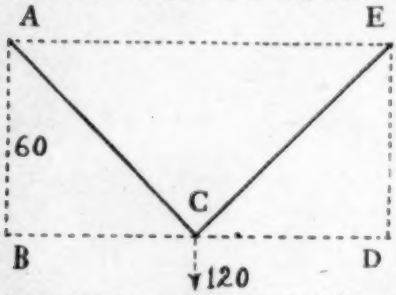
$$\therefore d = 5$$

This problem was also solved by Chas. H. Korns, Bradford, Pa., who calls attention to the fact "that atmospheric pressure must be neglected and that the pressure on the two surfaces, due to the weight of the liquids, shall be equal. If the pressure of the atmosphere is included, the density must be 1,200 or more."

Mr. Korns also submitted a solution for Problem 18 which is hereby acknowledged.

20. *From an examination paper of Morris High School, New York.*

A circus performer stands on the middle of a slack rope. The parts of the rope make right angles with each other. Calculate to one decimal the tension in each part of the rope, the weight of the performer being 120 lbs.



Solution by Gertrude L. Roper, Detroit, Mich.—

Since angle ACE is a right angle, and since AC=CE, ∴ angle CAE= angle AEC=45°. ∴angle BAC= OEC, complements of equal angles.

Since angle ABC = angle EDC, being right angles, ∴ angle ACB = ECD=45°.

∴ triangle ABC and triangle EDC are equal isosceles right triangles. By the definition of equilibrium the downward force of 120 lbs. is balanced by the two upward forces AB and ED. Since these are equal and the triangles isosceles, AB=ED=60= BC=CD.

Then $AC=\sqrt{AB^2+BC^2}=60\sqrt{2}=84.852$ lbs tension in each part of the rope.

This problem was also solved by G. B. M. Zerr.

ARTICLES IN CURRENT MAGAZINES.

American Forestry for March: "The Battle for the Weeks Bill," illustrations from the White Mountains by Charles A. Lawrence, Lynn, Mass., the Southern Appalachians from the United States Forest Service; "Growing Oak Trees," by Edward W. Hocker; "Forest Problems in the Philippines" (concluded), by Barrington Moore; "The Effect of the Forest upon Waters" (translation), by Mildred A. Castle; "Stories Told in Ranger Camps, No. 2," by Charles Howard Shinn.

American Naturalist for April: "The Origin of the Electricity Tissues in Fishes," Ulric Dahlgren; "The Material Basis of Mendelian Phenomena," Reginald R. Gates; "Mendelian Phenomena Without de Vriesian Theory," Dr. W. J. Spillman; "The Evolution of New Forms in Viola through Hybridism," Ezra Brainerd; "Tertiary Archhelenis," Dr. A. E. Ortman.

Astrophysical Journal for March: "On a New Mounting for a Concave Grating," Albert Eagle; "The Absolute Wave-lengths of the H and K Lines of Calcium in Some Terrestrial Sources," Charles E. St. John; "Some Photographic Phenomena Bearing upon Dispersion of Light in Space," Herbert E. Ives; "On the Application of the Laws of Refraction in Interpreting Solar Phenomena," J. A. Anderson.

Auk, The, for April: "Notes on Some of the Rarer Birds of Washtenaw County, Michigan," N. A. Wood; "An Apparently New Species of Carrion Hawk of the Genus *Ibycter*," William E. D. Scott; "The Tagging of Wild Birds: Report of Progress in 1909," Leon J. Cole; "The Courtship of Golden-Eye and Eider Ducks," Charles W. Townsend; "Birds Observed in Saskatchewan During the Summer of 1909," John F. Ferry.

Journal of Geology for February-March: "Succession and Range of Mesozoic and Tertiary Floras," F. H. Knowlton; "Certain Valley Configurations in Low Latitudes," T. C. Chamberlin and R. T. Chamberlin; "The Anthracolithic or Upper Paleozoic Rocks of Kansas and Related

Regions," Charles S. Prosser; "The Age of the Earth and the Saltness of the Sea," H. S. Shelton.

Mining Science for March 24: "Occurrence of Marble," Arthur Lakes; for March 31: "Valuation of Ore Bodies," H. S. Denny; "The Limit of Deep Coal Mining."

Nature Study Review for March: "Nature-study and the Bobwhite," C. F. Hodge; "Factors in Bird Mortality," Isaac E. Hess; "Bird Identification Chart," F. L. Charles; "Nesting Houses for the Birds," G. H. Trafton: "Colored Plates for April Number"; "Lessons on the Robin," T. L. Hankinson; "An Experiment in the Teaching of Biology," C. M. McConn; "Acknowledgment"; "Some Observation on Robin Nests," Fred L. Charles.

Photo-Era for March: "The Sixth American Photographic Salon," C. Yarnall Abbott; "Rendering Motion in Pictorial Photography," H. B. Whister; "Photography of the Snow," W. B. Post; "Our Exposure-Guide in a New Dress," Edward B. Johnson.

Popular Astronomy for April: "Achromatic and Apochromatic Comparative Tests," E. D. Roe, Jr.; "The Tilting of the Earth's Axis and the Glacial Epochs," F. J. B. Cordesio; "An Historical Examination of the Connection of Colixtus III with Halley's Comet," William F. Rigge; "Has the Moon a Rotatory Movement?" E. F. del Rincon and A. J. Miller; "Planet Orbits III," Thomas C. Ryan.

Popular Science Monthly for April: "Laws of Diminishing Environmental Influences," Dr. Frederick Adams Woods; "The Leading School of Tropical Medicine," Dr. Edward Nelson Tobey; "The Growth of a Language," Dr. Charles W. Super; "The Denominational College," Dr. Ivy Kellerman; "The Trial of an Old Greek Corn-ring," Dr. Frederic Earle Whitaker; "The Population of the United States," Professor James S. Stevens; "Preservation of the Fisheries on the High Seas," Dr. Charles Hugh Stevenson; "The Research Work of the Tortugas Laboratory," Dr. Alfred Goldsborough Mayer.

Physical Review for March: "Ionization Produced by Entladungsstrahlen and Experiments Bearing on the Nature of the Radiation," Elizabeth R. Laird; "Relation Between Temperature of Electrodes and Voltage of the Electric Arc," C. D. Child; "Note on Water of Crystallization," W. W. Coblentz; "Studies in Luminescence, XI, The Distribution of Energy in Fluorescence Spectra," E. L. Nichols and Ernest Merritt; "On the Probability of an Inherent Relation Between the Electrical Resistance and the Hardness of Steel," Carl Barus; "The Absolute Values of the Moments of the Elementary Magnets of Iron, Nickel, and Magnetite," Jakob Kunz; "On Contact Difference of Potential in a Magnetic Field," E. P. Adams; "The Effect of Temperature on Fluorescence and Absorption, II, Fluorescence and Absorption of Canary Glass at Low Temperatures," R. C. Gibbs; "Some Photo-electric Properties of the Alkali Metals, III. The Dependence of Photo-electric Current on Wave-Length of Incident Light," F. K. Richtmyer; "Temperature of the Divided Bunsen Flame," Daniel W. Shea.

Scientific American for March 26: "Rapid Transit by Belt Conveyor"; "Condensed Facts about Halley's Comet," H. W. Greggs; "A New Telephoto Camera"; "Thermal Treatment of Steel Ingots," J. F. Springer; "Eggs of Carrion Forms," Percy Collins. For April 2: "Building the Huge Concrete Locks at Gatun"; "Novel Changeable Photographs," F. Honore.

School Review for April: "Four Instruments of Confusion in Teaching Physics," H. L. Terry; "Professor Münsterberg's Conception of the Problem and Content of Educational Psychology," Irving King; "The Exchange of Assistant Teachers between France and Germany," Oskar Thiergen; "A Rural High School," L. B. Hill; "Library Reading in the High School," Margaret Ashmun.

Technical World Magazine for April: "Half a Continent Under Canvas," Henry M. Hyde; "To Make 'Ole Miss' Pay," John L. Mathews; "How to Save Coal," Joseph W. Hays; "Every Farmer a Potato Breeder," Guy Elliott Mitchell; "A Million for a Smoke Eater," John Houston McIntosh; "Where Land Flows Like Water," René Bache; "Park for Biggest Skyscraper," Bailey Millard; "New Home for the British Fleet," Harold Shepstone; "Latest Successes in Flight," Charlton Lawrence Edholm; "Doom of the Gipsy Moth," William Thornton Prosser.

A CORRECTION.

Allow me to correct two errors occurring in the report of one of the subcommittees of the International Commission on the Teaching of Mathematics as given on Pages 358-360 of the April number of SCHOOL SCIENCE AND MATHEMATICS.

In the first place the name of the subcommittee is the Committee on State Supervision and Inspection, and not the Committee on "State Legislation" as your reporter puts it.

The second error is one for which the chairman of the committee alone is responsible. When the matter was written the most recent reports that had come to the notice of the committee showed that there was no effective state supervision of the high schools in any southern state. However, the facts are quite otherwise, as appears from the latest reports which have been made accessible to the committee through the kindness of Professor E. C. Elliott of the University of Wisconsin.

The Virginia Legislature enacted a law in 1906 by which the state gives to its high schools aid in amounts varying from $250 to $400, and this grant of state aid is conditioned on *careful inspection by an authorized representative of the State Board of Education.* By an earlier law the state was divided into five districts, each under the supervision of a district superintendent giving his entire time to the work. According to the last report of State Superintendent Eggleston, not only were all the high schools inspected during the year covered by the report, but the great majority of the elementary schools as well.

In North Carolina the legislature provided for a system of state inspection of high schools coupled with very liberal state aid in 1907. The amounts actually paid out the first year varied from $500 to $1,500 for each school. *A state high school inspector devotes his whole time to the work.*

In South Carolina "An Act to provide high schools for the State" was passed in 1907. By this act the state grants aid equal to 50 per cent of the local support up to $1,200 under certain restrictions. The State Board of Education, which was authorized to act as a State High School Board by the same act, makes careful examination before the grant is made and, moreover, provides for further inspection and classification.

The action of these three important southern states in providing for efficient state inspection coupled with liberal provision for state aid seems to me to mark an epoch in educational work in the South, if not in the whole country. In each case liberal appropriations have made the provisions of the acts effective. To see the tremendous importance of this legislation one has only to note that within a year after the enactment of the legislation practically *four hundred high schools* were organized in the three states under these acts. It is significant, also, that in 1907 Florida appropriated $65,000 to aid its rural graded, and high schools, but by reason of failure to make an addition to its tax levy, the provisions of the act remained inoperative at the time of Superintendent Halloway's last report, June, 1908.

By way of apology for the form of the report let it be said that the matter which is printed in SCHOOL SCIENCE AND MATHEMATICS was contained in a personal letter to another member of the committee who was to report to the federation meeting. It is only fair to say that the chairman of the committee never dreamed that it would be printed with all its pronouns in the first person singular.

E. B. SKINNER.

Chairman Subcommittee on State Supervision and Inspection.

FIRST YEAR SCIENCE.

By Hudson Sheldon,
Lowell High School, San Francisco, California.

The High School Section of the California Teachers' Association, at its December meeting in San Francisco, aroused considerable interest in the discussion of a general science course for high schools. The discussion was continued two days. Among those taking part were Dr. H. W. Fairbanks, Prof. Morgan, Mr. M. B. Nichols, Mr. E. W. Monroe, Miss Bridgeman, Mr. E. P. Carey, and Mr. A. L. Jordan. The discussion speedily resolved itself into an advocacy on the one hand of physical geography and on the other of an entirely new topic, general science, as the proper subject for first year instruction in science in the high school.

A committee to investigate present conditions in elementary science instruction in California high schools had issued a circular letter. Like all such letters, this appeal brought many answers of doubtful value. It appears that eighteen schools are now giving a course in general science and forty-seven are not, that twelve give no science to first year pupils, while thirty-one offer physical geography, and that a great increase in out-door work and observation is desirable. Forty-five teachers believe that there is need of a general science course, but, when the purpose and the content are discussed, it does not appear that the teachers in general have in mind a course differing greatly from physical geography as at present taught. The replies contained practically nothing that could indicate the content of a new course in general science.

The science teachers present followed the discussion with an abiding interest. The majority were in the attitude of inquirers, asking what general science has to offer that physical geography does not give. The criticisms on physical geography seemed to be to the effect that teachers are not a unit in their understanding of the purpose of the science and the means the science should employ, and that the teaching is more or less desultory. To many of those present the advocates of general science did not seem able to offer anything to remedy these faults. In fact, the chief objection made to the general science course was that it lacks coherence and definiteness.

Two conclusions may fairly be drawn from the discussion. The first is that physical geography offers a good working basis for introduction to high school science. Much has already been accomplished. This would be lost if the course were changed, and progress lies in the direction of more accurate definition of the course rather than in that of making the work more vague and general. The second conclusion is that the true field of a course in general science apart from physical geography is to prepare the way for high school science. Its place is in the seventh and eighth grades; but general science in the seventh and eighth grades, like all instruction in any grades, must be definite. The experiments must be directed to specific ends, and the organization must not be less precise than that of work in arithmetic or grammar.

Committees were appointed to consider the subject further and report in one year.

TEACHERS WANTED IN CHICAGO.

Owing to the opening of several new technical high schools in Chicago, there is demand for teachers in the following departments: (a) Blacksmithing, (b) Foundry, (c) Machine Shop, (d) Woodworking, (e) Electrical Construction, (f) Mechanical Drawing. Minimum requirements: The equivalent of a high school education, and three years of special training.

Teachers of manual training are also needed in the elementary schools.

Teachers of mathematics and science, especially physics and chemistry, are also in demand.

The examinations will be held in Chicago June 27, 28, 1910. Application blanks and further information may be obtained from the examiner, Room 829, Tribune Building, Chicago.

THE BIOLOGICAL STATION OF THE UNIVERSITY OF MICHIGAN.

The second session of the Biological Station of the University of Michigan will begin July 5 and continue for eight weeks, closing August 26, 1910.

The station is located on the shores of Douglas Lake, Cheboygan County, in northern Michigan, and is particularly well located for field and laboratory courses in zoölogy and botany. The work of the station is under the supervision of Professor Jacob Reighard, head of the Department of Zoölogy in the University of Michigan, as director. The active staff will consist of Dr. A. S. Pearse, Instructor in Zoölogy in the University of Michigan and Assistant Director of the Biological Station; Assistant Professor Raymond J. Pool of the Department of Botany of the University of Nebraska and Director of the Nebraska State Botanical Survey; Mr. Norman H. Stewart and Miss Lucie Harmon, Assistants in Zoölogy in the University of Michigan; Mr. F. A. Loew, Professor of Science in Central College, Indiana, will act as Assistant in Botany.

The courses of instruction will include: The natural history of invertebrate animals, field studies in vertebrate zoölogy, zoölogy for teachers, special work in research in zoölogy, first course in field and forest botany, mycology, systematic botany of seed plants, advanced work in research in botany.

Through the generosity of a friend of the University, two scholarships paying $50 each are available to students with considerable experience in biological work. Applications for these scholarships should be addressed to Professor J. Reighard, Ann Arbor, Michigan.

A special bulletin of the station may be had by applying to Professor E. H. Kraus, Secretary, University of Michigan, Ann Arbor, Michigan, to whom applications for registration must be sent before June 1, 1910. Since only a limited number of students can be accommodated, registration will close on that date.

BOOKS RECEIVED.

Fungous Diseases of Plants. By Benjamin Minge Duggar, Professor of Plant Physiology in Cornell University. 8vo, cloth, 508 pages, illustrated, $2.00. Ginn & Company, Publishers, Boston.

Proceedings of the Thirteenth Annual Meeting of the New York Science Teachers' Association. Syracuse 1908 meeting. 138 pages. Published by the University of the State of New York.

Thirty-eighth Annual Report of the Board of Directors of Kansas City, Missouri. Cline Printing Company, Kansas City, Mo.

The Strength of Ten, Telling What Manhood is and How a Boy May Win It. By Winfield Scott Hall, Northwestern University Medical School, Chicago. B. S. Steadwell, La Crosse, Wis.

Div-a-let, Division by Letters. By W. H. Vail. 70 pages, paper. The Revell Company Press, Chicago.

Soil Fertility and Permanent Agriculture, by Cyril G. Hopkins, University of Illinois, Urbana; 8 vo. cloth, XXIII + 653 pages, illustrated, $2.75, Ginn & Company, Boston.

A Class Book of Physics, by R. A. Gregory and H. E. Hadley; 1909, pp. 487, Macmillan Co., London.

Elementary Course in Perspective, by Sherman M. Turrill, with 16 illustrations and folding plates; 1910, pp. 71, D. Van Nostrand & Co., New York; price, $1.25, net.

The Simple Carbohydrates and the Glucosides, by E. Frankland Armstrong; 1910, pp. 112, Longmans, Green & Co., New York, price $1.20 net.

U. S. Dept. of Agriculture; Organization, Work, and Publications of the Agricultural Education Service; pp. 15, 1910.

Free Publications of the Department of Agriculture classified for the use of Teachers; pp. 29, 1910.

BOOK REVIEWS.

Geographical Essays, by Professor William Morris Davis, Professor of Geology, Havard College. Edited by D. W. Johnson. 774 pages. Ginn & Co.

This is a collection of twenty-six of the more important geographical essays of Professor W. M. Davis which have appeared from time to time in the various educational magazines and scientific journals. The articles are well arranged under two titles: The Educational Essays and the Physiographic Essays.

The discussions bearing upon the educational aspect of geography in the schools are remarkable for the clear treatment of the various secondary school problems. "The Inductive Study of the Content of Geography" is worthy a careful reading by those who are at present seeking to reform or inject new material into the secondary school geography. In this same connection, "The Teaching of Geography" offers abundant suggestions which apply to many of the present ideas which are being advocated as improvements in the teaching of physical geography. "The Progress of Geography in the Schools" is an analytical summary of the modern development and application of physiography, regional geography, and ontography to geographical instruction. These educational essays in the past have been of practical value to the active teachers, and in the future they will continue to offer a fund of live ideas which will have a stimulating influence upon geographical teaching.

The fourteen discussions of the physiographic aspects of geography will prove of special interest to the high school instructors who desire to teach modern physical geography. Full amplification and a clear discussion are presented of the geographical cycle in its various complications. Much evidence is offered, in the essay on "The Peneplain," to satisfy certain criticism of the idea of wholesale planation and its accompanying term, peneplain, which is now quite generally used. The discussion of base-level, grade, and peneplain is valuable to teachers who desire to use accurate terms in physiographic studies. The treatment of the rivers and the

valleys of Pennsylvania is an excellent illustration of the application of the ideas of systematic physiography. In "The River Terraces of New England," the relation of the river action to the complicated topography, resulting from glaciation in the New England valleys, is discussed and the deductions tested by many observations. The theory of ice action on highlands is developed in "Sculpturing of Mountains by Glaciers." This is followed by an article, "Glacial Erosion in France, Switzerland, and Norway," which contains observations on ice action on mountains and a full discussion of hanging valleys. The development and denudation of block mountains receive a full treatment in the last one of these essays and the mountains of the Great Basin are the types selected for illustration. These various discussions are full of rigorous, systematic physiography, and serve as excellent illustrations of the application of rational methods to the problems of physical geography. W. M. GREGORY.

The Teaching of Geography. By William J. Sutherland. Published by Scott, Foresman & Co., Chicago, Ill. 1909. 295 pages.

This book is a crystallization of the movement to modernize elementary school geography which has been in progress a number of years. Secondary teachers will appreciate the discussion of the nature and scope of geography as outlined in the fore chapters. The ideas of the text will prove of material benefit to those who are still floundering in the formal statement and "spot location" geography of a generation or more ago. "The failure of geography in the past is due to the fact that it has been made a memory drill on unrelated items and isolated facts." A concise summary of the elementary school geography problem occurs in the following: Formal fact teaching must be replaced by concrete problems of human interest, the rational element must be more generally recognized, the materials of geography must be carefully selected and types suitable to the community developed, the social or human geography must be more emphasized and home geography must be recognized as the concrete basis of an elementary geography course.

The book not only "instills into the minds of the teacher the true nature of geography" but it furnishes much that is usable in specific suggestions, in selection of materials, text-books, pictures, maps, charts, and models. The work lacks the indefiniteness of ideas and the broad sweeping generalizations that characterize many of the teachers' manuals and articles by specialists in this field of geography. The book is the result of a successful teaching experience in which the author has seen many problems and has made a commendable contribution in attempting their solution. The results which are embodied in this book will be well received.

W. M. GREGORY.

First Principles of Chemical Theory, by C. H. Mathewson, Ph.D. John Wiley & Sons. 1908. Pp. 123. Price, $1.00.

The author of this book uses it with the first year students at the Sheffield Scientific School as a reference text in connection with a short course of lectures on Chemical Theory. A period of six weeks, immediately following the first four months' instruction in General Chemistry being devoted to work of this nature.

The purpose is to offer very early presentation of leading principles which are of material assistance in teaching the beginner to properly explain and correlate his experimental results.

The introductory chapter outlines the leading principles and common

conventions pertaining to the study of general inorganic chemistry; then the natural classification of the elements is briefly considered, familiarity with the halogen group alone being assumed; this is followed by three chapters on determinations of molecular weights, atomic weights and calculation of formulas.

Chapter six is given to the consideration of osmotic pressure and related phenomena with particular reference to dilute aqueous solutions of acids, bases and salts, following which the electrolytic dissociation theory, mass action, heterogeneous equilibrium and thermochemistry are each discussed in its own chapter.

A knowledge of these principles based upon the student's own observation of experiments would undoubtedly increase his interest in the subject, give him clearer ideas and make his work more profitable, but that such a knowledge can be gained in a six weeks' course, by the average freshman in our universities, does not seem probable to the reviewer.

The discussion of the topics indicated in the several chapters is clear, and for general reference, without too detailed treatment of the subject this book is to be commended.

An index completes the volume. A. L. S.

The Romance of Modern Chemistry, by James C. Philip, D.Sc., Ph.D., Assistant Professor of Chemistry at the Imperial College of Science and Technology, South Kensington. Pp. 348, with 29 illustrations and 15 diagrams. J. B. Lippincott Company, Philadelphia, 1909. Price, $1.50 net.

What is a text-book on chemistry? The question is a hard one to answer. Whatever such a book is, it *is not* a romance.

In the case of "The Romance of Modern Chemistry" it is difficult in a brief review to give the reader a satisfactory idea of what Dr. Philip has written. Even an enumeration of the headings of the chapters would not convey much of an idea, as can be seen by examining a single chapter whose title is "Valuable Substances from Unlikely Sources." The real topic of this chapter is "the by-products of a gas works." Because of the sulphur in the coal, hydrogen sulphide appears in the gas. The removal of this gas may result in the production of sulphur, sulphuric acid, or ammonium sulphate. Hydrocyanic acid also appears in the coal, is extracted, and converted into potassium ferrocyanide, which is used in turn for the preparation of Prussian blue, printers' ink, or potassium cyanide. "This latter compound is extensively employed in gold extraction and in electro-plating." From the gas liquor and tar come ammonium sulphate, a solvent for rubber, wood preservative, benzene, toluene, phenol, naphthalene, and anthracene—all those hydrocarbons that form the basis of aniline and the endless colors, photographic materials, lyddite, saccharine, etc., which are derived from it. "Anything from a salve to a star," as *Punch* says—

> "There's hardly a thing that a man can name
> Of use or beauty in life's small game
> But you can extract in alembic or jar
> From the physical basis of black coal tar.
> Oil and ointment, and wax and wine,
> And the lovely colors called aniline;
> You can make anything from a salve to a star,
> If only you know how, from black coal tar."

A text-book would deal with equations and problems and theories (in heavy type). The "Romance" starts out on "Explosives and explosions," and gives a very interesting and striking explanation of the rate of chemical reaction. In similar manner the chapter on "How Fire is Made" discusses the allotropic forms of phosphorus, catalysis, oxidizing agents, and spontaneous combustion. The reader does not need equations or symbols in order to understand the author. The text-book proceeds logically, the romance effectively though not in logical sequence. From the former the student learns more chemistry, from the latter he enjoys chemistry more.

The title of the book is sensational, the picture on the cover likewise, the style is popular and easy, and yet the book is an excellent text-book on chemistry with all the emphasis on applications to matters of everyday experience. For supplementary and review reading it is particularly valuable. F. T. J.

First Year Chemistry, by Wilhelm Segerblom, A.B., Instructor in Chemistry at the Phillips Exeter Academy. Exeter Book Publishing Company, Exeter, N. H., 1909. pp. XXV+410. Price, $1.50.

This book is practically an outline for the laboratory work, and "embraces as much of the essential facts and influences of chemistry as the ordinary student can assimilate in one year's study of the subject." The author's plan is to use the inductive method rigorously in the first ninety experiments, something more than a third of the book, beginning with the metals; then the strictly inductive method is discarded in considering the theory and descriptive chemistry. In general the 169 experiments are well chosen to illustrate the various points to be studied and the directions clearly stated, but too often the pupil is given an unnecessary hint as to the result looked for; thus he is told to note the *increase* in weight when copper and other metals are heated in the air; *change* would have been better. Or in burning carbon monoxide he is told that the flame is *blue* instead of being asked to observe its color. Again, he is told the properties of sodium before experimenting with it.

The definition of combustion, p. 56, does not include the burning of such substances as charcoal and iron, which do not "burst into flame." Precipitate as defined p. 164 would include a gas, although it is not usual to regard effervescence as precipitation. The definitions of hydrolysis, p. 296, and of acids, p. 343, are not well chosen.

The use of the terms hydrate and hydroxide as synonomous, and the regarding a base as a metal, metallic oxide, or metallic hydroxide, pp. 317 and 344, are confusing and not in accordance with the best usage of to-day.

Oxygen is usually taken as the basis of density, but the author clings to the old hydrogen standard.

The action of iron upon sulphuric acid and of zinc upon hydrochloric acid are not commonly regarded as reduction, though so classified on page 342.

Experiment 168 gives the amount of salt in 10 c. c. of the solution but not the amount of salt dissolved in 10 c. c. of water.

The laboratory equipment per pupil as suggested for the course here presented is too bulky and too expensive for most schools.

The typography of the book is good, but many errors were overlooked by the proofreaders, especially on page 324. A. L. S.